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EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

The Explosion on H. B. M. S. S., Thunderer.—Forty-five lives have been lost by the explosion of a boiler, on the fourteenth of July last on board the British man of war *Thunderer*, the circumstances of which are well known to our readers from other journals, and will be found briefly noted by the Secretary of the Institute, at the meeting reported in this number of the JOURNAL. The coroner's inquest which has resulted in a verdict of "accidental death," although accompanied with a finding that all the valves were stuck or closed down so that "the explosion resulted from excessive pressure," gives little satisfaction to any portion of the English community. Accidents *are* preventible and the end and purpose of a coroner's inquest, after an accident, is to exhibit judicially the circumstances of occurrence together with the malice or inadvertence which had allowed the disaster to ensue. It is the failure of the inquest to show either criminal or

inconsiderate cause for this accident that gives ground for so universal dissatisfaction.

The Coroner seems to have had the advice and assistance of one of the ablest of English engineers in this line of engineering, and as his opinion upon the facts coincided with the testimony of the few witnesses examined, and especially with the conclusions of the principal witness, F. J. Bramwell, C. E., and as all agreed in absence of malicious intent or blamable neglect, he did not recognize the desirability if not necessity of pursuing the inquiry to proximate causes.

It sounds somewhat like a paradox, to say that it is almost probable that any clear-headed lawyer, himself wholly uninformed on mechanical subjects, cross-examining the witnesses before a jury who were to be instructed from the very groundwork, would have elicited more information as to the cause of this disaster and the ways of prevention of future accidents, than has come out in this inquest.

Admit all the facts as given by Mr. Bramwell—and no other witness adds to them—a train of cross-examination which should have shown what constitutes a safety valve? what relation the steam gauge bore to the safety of the boiler? what caused the boiler to rupture in its peculiar way?—a kind of cross-examination which an uninformed person, who wanted to know, would have instituted, might have been productive of unexpected results. Thus with regard to the kind of valves called in this case safety valves—which proved so dreadfully misnamed, the general and accepted use could have been pleaded in showing no particular negligence or exceptional error in judgment —but were they safety valves? Upon such an inquiry it would have appeared if loosely fitted in the wings and easy in the guide at the head of the long spindle, they would have been likely to lift, so long as they stood upright, when the pressure in the boiler exceeded the resistance of the load of weights. Under this condition they would preserve a definite pressure in the boiler, but in sea service and with a rolling ship the effect of the weight would by no means preserve a definite pressure—a large portion of the load would be carried by the stems and wings. When the vessel rolled 30° the valves (if supposed to be divested of frictional resistance) would be relieved for 13·4 per cent. of the direct load, and at 45° of 29·3 per cent. That is, if the maximum normal load were equal to 30 lbs. pressure per square inch, the valve would lift at 26 pounds pressure in the first case, and 21·2 pounds in the second. This difference of pressure would be enough to

render a steamer unmanageable, as a man of war in a heavy sea, although it might be tolerable in the merchant service. [It was admitted that springs were substituted for weights in the latter service.] The load of weights on each valve was about 800 pounds and the weights were strung upon a spindle of 1¼ inches in diameter and about 18 inches long from the top of valve seat to the spindle guide. The swinging of this immense weight on a slender, soft (not hammer hardened) brass spindle, although in the quietest part of the ship, cannot be regarded as a desirable mechanical arrangement. But the use of three wing guides for the valves, in the seats, would meet the disapproval of most constructors. Four wing guides where there is any sidewise pressure are much less apt to bind—the angle of contact of the face of the guides with the side of the hole in the valve seat is much more favorable for four wings than for three. But the poppet valve with a pin guide is admitted to be preferable to any wing valve, for ease in lifting. To carry these heavy weights, and to close tight on the seats after the valves had once lifted, these valves had their wings and the top of the spindles well fitted. There were two valves in the same casting and the expansion of the pair of seats—directly exposed on their under side to the steam in the boiler, while the spindle guides at the top were comparatively cool, seems to have bound the wing guides in seats, so that the valves failed to operate at all, until some unknown, excessive pressure ruptured the boiler. The hand wheel lifting contrivance, by which one of the two safety valves could be forced up from its seat, in case it stuck, is a more than doubtful improvement as a substitute for the old lever and cord with which the fireman *felt* the pressure in his boiler.

The best American practice in safety valve construction is a loose disc valve, without any bottom guides whatever, the contact of the valve with the seat being ensured by guiding the spindle above and close down to the disc. The bearing surface of the disc is made a portion of a sphere, and the seat is a narrow edge of conformable shape; the disc is ground to fit the seat by a pestle and mortar movement, so as to be tight in whatever position contact is made, within some limit of looseness of joint between the stem and the disc. The lever bears upon the end of the valve spindle, and is threaded through a loose bridle at the top of spindle, the end of which lever is held by a balance spring, so that the fireman can test his safety valve at any moment. It is customary to carry a cord or chain from

the safety valve to the engine room, to allow the engineer to try the safety valve for himself if he chooses.

The areas of the safety valves for the boilers of the *Thunderer* were in accordance with good American practice, on the supposition of a combustion of not much over twenty pounds of coal per square foot of grate per hour.

Some persons are disposed to lay stress upon the negligence which allowed all the steam valves of the boiler which exploded to be or to remain closed; but, in an engineering point of view, this condition could not be considered as the cause of the disaster. The safety valves were intended to meet just this contingency; and if they had not been unreliable in the extreme they would, without the least question, have done so. Not that the negligence can be excusable, but that this particular negligence was one of the known chances of operating boilers, and the accident arose from the failure of the provision of safety valves to meet it.

The steam gauge was a snare and delusion. Are not all of them so? If there is an engineer who has not stood in stupid helplessness before a row of discordant steam gauges, and has not returned to *feeling* his safety valves to find where his steam was in his boilers, that engineer is in the British navy—he is surely not to be found elsewhere. Steam gauges, as well as glass water level gauges, when in order, have their place in the *convenience* in working of boilers, and, possibly, in the promotion of safety, in giving each of them one more sense (that of sight) to the fireman; but the safety valve which can be lifted, and the gauge cocks which can be blown, will for all time remain, preëminently, the tests of reliance.

The boilers were of an antiquated and nearly obsolete type—unsafe at any moderate pressure, and unsuited for use with an engine built in accordance with good practice within the past ten years. Their broad, flat surfaces invited accident, either from unavoidable imperfections, or the rusting away of the stays. These flat surfaces were stayed in 16 inch quiltings, by 1¼ inch screw stays (about 1·22 inches at the root of the threads), and the stays broke off or drew through the ½ inch thick plate. The load on each of these stays was of course 256 times 30 pounds, = 7680 pounds, on 1·17 square inches of section of iron in the bolt, = 6600 pounds on each square inch. They would each, probably, have carried eight times this load, supposing none of them to have been strained in threading, and no

defect existed; but the limit of elasticity is reached at three times, and in screwed bolts from iron of 50,000 pounds tensile strength, this point (20,000 lbs.) is where the probability of failure from impairment or defect begins to have definite value; so that the stay bolts could not, in an engineering value, be taken as over *three* times in excess of their strength. But this admission of possible weakness in ever so small a proportion of the number of the stay bolts employed, should be applied to what happens when any one of them fails, and the effect upon the adjacent ones—whether in case of the failure of one stay bolt, those next to it could carry its load. When it is considered that the breakage of a defective bolt would be sudden, and the effect on those near it would be of the nature (in part) of a blow, and that the strain would not be a fair one, but, with a leverage, it is quite evident that this wide spacing trenched on the limits of safety.

The facts here given, and perhaps others, would have appeared in evidence if the inquest had been directed by any barrister without predisposition to show not only how, but why, this accident occurred. The dissatisfaction with the verdict in England is because this important point was not fully elucidated. If this was an *accident* pure and simple, and if the preceding catastrophes in the British navy were accidents, the belief that these iron-clads are very dangerous vessels will be quite generally entertained in Great Britain.

Franklin Institute.

HALL OF THE INSTITUTE, Sept. 20, 1876.

The stated meeting was called to order at 8 o'clock P. M., Vice-President Chas. S. Close in the chair.

There were present 60 members and 4 visitors.

The minutes of the last meeting were read, and after amending verbally, were adopted.

The Actuary presented the minutes of the Board of Managers, and reported that since the last meeting of the Institute, there have been 14 persons elected members of the Institute, and the following donations made to the Library:

Sixth Annual Report of the United States Geological Survey of the Territories, for 1872, by F. V. Hayden. Washington, 1873. From Hon. Chas. O'Neill, House Rep.

Minutes of Proceedings of Institution of Civil Engineers. Vols. 43, 44. Session 1875–6. Parts 1 & 2. London, 1876. From the Institution.

British Patent Reports, issued between Feb. 19 and May 13, 1876

Abridgments of Specifications. Wearing Apparel. Div. III. Foot coverings. Ditto. Harbours, Docks, etc., 1617–1866. Alphabetical Index of Patentees and Applicants for Patents, for 1873. From British Patent Office.

[List of Donations to the Library will be continued in next number.]

From the Committee on Library, the Secretary presented and read the following:

Phila., Sept. 15, 1876.

Mr. Jacob B. Knight, Secretary,

Dear Sir:—I send by bearer a collection of old volumes, chiefly on chemistry, numbering about eighty, which it is my purpose to present to the Franklin Institute; as also those I have heretofore deposited with the Institute, either bearing my name or that of my late father, Adam Seybert. Very truly yours,

426 Walnut Street. Henry Seybert.

Mr. Bullock, Chairman of the Committee on Library, presented the following:

The donation of books made by Mr. Seybert numbers over 500 volumes, and is a valuable and acceptable gift. Some of the volumes belong to scientific serials, and serve to complete the sets to which they belong, now in the Library. The Committee on Library, desiring to properly acknowledge the substantial character of the donation, offers the following resolutions:

Resolved, That the thanks of the Franklin Institute be and are hereby presented to Mr. Henry Seybert, for his valuable gift of the books heretofore deposited with us; as also for the additional volumes lately received.

Resolved, That the Secretary of the Institute be directed to forward a copy of these resolutions to Mr. Seybert.

On motion the resolutions were unanimously adopted.

The Secretary reported from the Committee on Sciences and the Arts, that at its last meeting it recommended the award of the Scott Legacy Premium and Medal to Chambers, Bros. & Co., for their brick-making machine.

The Secretary presented his report, which embraced a new relay sounder for electro telegraphing, invented by Professors E. J.

Houston and E. Thompson, of this city; a steam canal-boat, the invention of Jos. W. Dilks, of Philadelphia; a grid-iron stage and depositing dock for docking vessels, the invention of Messrs. Clark and Stanfield, London, England; and an illustrated account of the causes leading to the explosion of one of the boilers on the British turret ship *Thunderer*;* and also a description, by Mr. R. Briggs, of a remarkable curve on Southern Pacific R. R., at Tehichipa Pass, California.

The Secretary announced that the usual session of the Drawing School will commence on Monday, Oct. 2, prox., under the direction of Prof. L. M. Haupt: that Mr. D. S. Holman will open a class in Phonography, under the auspices of the Institute, on the same date, and also, that the lectures during the coming winter will consist of two courses of sixteen lectures each, one being elementary lectures on such subjects as are likely to be useful to apprentices and artisans; and the other course, the usual illustrated scientific lectures—one of each course to be given each week, beginning about the first of November. He called attention to the fact that the expenditure by the Institute for these lectures is very large, and appealed to the members to give them the hearty support which they deserved.

Under the head of Deferred Business was taken up the resolutions of Mr. Jones, offered at the May meeting, relating to the adoption of the Majority Report on the Metric System of Weights and Measures, when, on motion, the further consideration of the subject was postponed to the stated meeting in October next.

Mr. Chabot moved that the meeting do now take up the resolution of Mr. Orr, relative to the construction of a ship canal across the great American isthmus, offered at the last meeting, and laid on the table. The motion was lost.

The Secretary read a letter from the Society of Arts of Geneva, Switzerland, accompanying and presenting to the Institute an example of the medal struck in commemoration of the one hundredth anniversary of the foundation of that society. On motion it was

Resolved, That the medal be accepted, and the Secretary be directed to return a proper letter of acknowledgment.

Mr. J. J. Weaver offered the following as an amendment to Art VII, sec. 2, of the By-laws, and it was seconded by Mr. Jas. Eccles: "He shall notify the members of the Institute of the monthly meet-

* See page 226.

ings by postal card, stating the nature of the business to be brought before it."

On motion of Mr. J. J. Weaver it was

Resolved, That we respectfully request the Board of Managers to send notices for each monthly meeting, to all members in good standing.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

The Improvement of Hell Gate Channel, New York.—The final explosion at Hallett's Point occurred on Sunday, the 24th inst., at 2.50 P.M., and was an exceedingly successful event. Somewhat more than 50,000 pounds of explosive material, mostly dynamite, were charged; and the explosion of the whole, so far as observation or report was an indication, was nearly instantaneous. At this time the completeness of the explosion has not been fully ascertained, but there is every reason to believe that every portion of the explosive was discharged. Observations over the surface of the water in different directions showed the extent of explosion reached, as indicated by the disturbance and foam, in each direction, out to the limits of the mines. At these limits the water appeared to lift three or four feet, and this lifting seemed over the whole surface, which, after a momentary interval, broke and spurted up in columns, variously estimated at from twelve to twenty feet high, followed by the cloud of black steam which is formed by hot vapor laden with condensed moisture. No report accompanied the explosion—a stifled thud and slight shock to the ground was the sole outward exhibition beyond the disturbance of the water. On the Point itself a wave of water must have run up some eight or ten feet, but the commotion did not extend to neighboring shores, although some of them were not over 1000 feet distant, except as a heavy wash of a foot or two. Not a fragment of rock was thrown out of water, and yet the whole surface of over 100,000 square feet of rock, ten feet in thickness, was lifted, rent and dropped into the mines beneath. No masses of rock were displaced, and as the explosion was timed for slack-water at full tide, no obstruction was made in the regular channel and the navigation of the Sound has not been in the least interrupted. Twelve to fifteen feet of water now exist where the rocks were previously exposed at low tide, and after removal of shattered material there will be twenty-six feet depth at the same

point. The explosion leaves from 80,000 to 90,000 tons of loose rocks to be removed. The accomplishment of this enginering feat without disaster, and with so successful a result, is an enviable record for General Newton, U. S. Engineer, who has charge of the Hell Gate improvement.

Thallene.—A communication to the Editor, from Prof. Henry Morton, President of the Stevens Institute, referring to the article of Doct. Tweddle in the JOURNAL (this volume, page 204), claims that the impression given by Doct. Tweddle's language as to the isolation of the hydro-carbon, to which Prof. Morton gave the appropriate name of Thallene, is in some respects erroneous. Doctor Tweddle wrote: "this substance was examined by Prof. Morton, to whom I sent some for examination." Prof. Morton writes that while he was engaged in 1872 in the study of fluorescent substances, he was furnished by Prof. Horrford, with about two ounces of tarry residuum from petroleum distillate, which residuum he had obtained in Pittsburgh. From this Prof. Morton extracted a gram or two of a gum solid—the quantity was entirely too small for study or analysis. On application to Prof. Horrford for more of the crude distillate "he referred me to Doct. Tweddle, upon whom I called in New York." "I called upon this gentleman, explained what I had done and asked a further supply of the tar, which was then and afterwards promised, but I have never received an atom of the substance from him. Subsequently I obtained an abundant supply from the works of Mr. John Truax, of Pittsburgh (from whom the first tar on which I experimented was derived), with which the researches ending with the isolation of 'Thallene' were made." An account of these researches, descriptive of the methods employed in isolation and of some of the properties of thallene will be found in the *Chemical News*, 1872, Vol. XXVII, p. 272, and in other chemical and philosophical journals of the same date. The investigations of Prof. G. F. Barker, of the University of Pennsylvania, and of Doct. Tieman, of Berlin, indicate, that Thallene has the same composition as Anthracene, viz., $C_{14}H_{10}$ while the chistalline form, solubilities and fusing points, and the chemical combinations with bromine, chlorine, etc., show that it is unlike that body. Prof. Morton objects to the use of the name Thallene as given to a mere product of distillation, by Doct. Tweddle (see page 207) when it has been appropriately associated with a definite separate carbon compound.

Among the exhibits of the Steven's Institute of Technology at the Centennial, Main Building, T 76, will be found the following specimens, the latest of which were prepared by Prof. Morton, two years ago:

No. 1.—Crude thallene, washed with benzine, prepared in 1872.

No. 2.—Crude thallene, washed with benzine and hot alcohol, prepared as above.

No. 3.—Thallene, by repeated crystallization, prepared as above.

No. 4.—Thallene C. P.

No. 5.—Thallene chinone.

No. 6.—Thallene bromide.

No. 7.—Thallene chloride.

No. 8.—Thallene picrate.

No. 9.—Sublimed Thallene.

No. 10.—Solarized Thallene, or petrollucene.

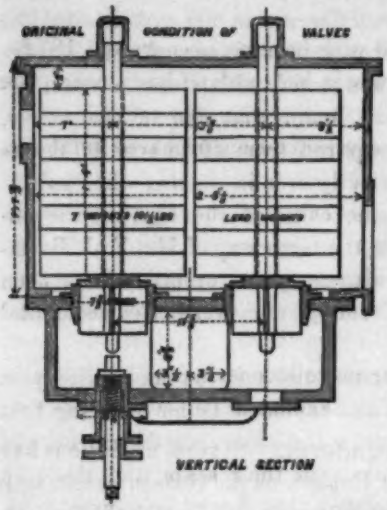
Boiler Explosion on the Thunderer.—Several explosions have quite recently occurred on board English naval vessels, resulting in loss of life, and have called forth some severe criticisms from the leading English engineering journals. The most important of these as regards loss of life and property, and the peculiar circumstances attending it, was that on board the *Thunderer*, which occurred on July 14th, 1876—the explosion of one of eight main boilers with which she was fitted, and resulting in the death of 47 persons.

The *Thunderer* is a twin-screw turret ship, and was built some three years ago, and had made her trial trip, but had not run the measured mile as required to determine her speed, and at the time of the explosion was steamed up for the purpose of making that trial.

The boilers were of the rectangular multitubular type, about 15 feet wide (front), 13 feet high, and 10½ feet deep (length of tube), such as have been in use in the English navy for many years. The explosion carried away nearly the whole of the front top plate, about 15 feet long by 4 feet 3 in. wide.

The evidence shows that the boiler which exploded was fitted with two steam stop-valves, one 10½ in. diameter leading to the main steam pipe and thus connecting with the other boilers, and the other valve, 6 in. diameter, connecting with the auxiliary steam pipe, and also with two safety valves, 5⅞ in. diameter; these four valves being the only outlets for steam.

The safety valves were of the three wing type, with guide spindle, reaching to top of valve box and loaded with lead rings, both being set in one cast iron casing or box, as shown in the illustration.



One valve in each valve box was fitted with a lifting screw underneath, by which it could be lifted so as to relieve the pressure in the boiler. A pipe was attached to the valve box for conducting away the escaping steam in such a manner that it could not be seen in the stoke hole.

This boiler (like all the others) was also fitted with a Bourdon steam gauge, marked to a pressure of 35 lbs., the working pressure being 30 lbs.

At the time of the explosion *both the steam stop valves were closed*, as shown very positively by the evidence; and very little effort seems to have been made to ascertain who was responsible for this blunder.

On the day of the accident, when steam had been raised to 26 lbs. pressure, as indicated by the gauges on the other boilers, and the engines were working slowly, it was observed that the gauge on this one showed *no pressure*. A workman was sent to ascertain what was the difficulty, and was told to break the glass and work the hand, which he did, and the hand rested on the 15 lb. mark. An examination of the gauge after the explosion showed that at a pressure of about 60 lbs., or anything above that amount, the hand would be carried around to the wrong side of the zero pin, and indicate no pressure, but if in the breaking of the glass and working the hand it should accidentally be carried over the pin, the hand would pass on to about the 15 lb. mark, where it would be thrown out of gear and the pressure could be raised to any point, without the gauge indicating more than 15 lbs. Experiments made after the explosion, show that this action did take place in the gauges attached to the other seven boilers, at pressures ranging from 52·94 lbs. to 62·07 lbs.

The safety valve box was bolted to the front plate of the boiler at its top edge, and was, consequently, carried away by the explosion,

and much injured; but a careful examination showed no evidence of its having been tampered with, and both valves turned freely in their seats, although the fit of the wings was very close. It was suspected that the valve might stick from the difference in the expansion of the brass valve and seat and the cast-iron case, and, accordingly, a valve box from one of the other boilers was tested with steam a considerable number of times, when it was found that one of the valves, weighted to 30 lbs. per sq. inch, required from 40 to even 60 lbs. to lift it on first heating, although perfectly free in its seat when cold.

The decision arrived at as to the cause of the explosion is embodied in the following extract from the testimony of Mr. F. J. Bramwell, one of the leading scientific witnesses, and seems to have been acted on by the coroner's jury in forming their verdict of accidental death:

He "could, therefore, only suppose, unlikely as undoubtedly it appears, that both safety valves of the exploded boiler on being first heated as they were from cold water in the boilers, on the morning of the 14th of July, remained stuck down in their seats, and the stop valves being shut there was accumulated that heavy pressure which the bulging of the sides of the smoke box and of other parts of the exploded boiler proves, must have prevailed there; an excessive pressure also consistent with the behavior of the pressure gauge, and with the marks of the spindle of the safety valves."

This difficulty with close fitting safety valves set in iron chambers, has long been known and acted on in this country, but seems not to have been observed in the English navy, although so thoroughly established by experiment after this explosion. The writer has often met with this trouble in the valves of hot water pumps and safety valves, where they were of brass set in iron chambers.

This difficulty may also be developed after several days' use. Each time the valve is heated the brass seat has the tendency to expand more than the iron case or chamber, but is prevented from doing so by the surrounding iron, and is, therefore, slightly compressed in diameter, and after this is repeated several times the permanent reduction may become more than the original clearance of the valve in its seat.

It is quite common for such valve seats to become quite loose, and when not fastened in place otherwise than by the friction of the fit, have been known to adhere to and raise with the valve. K.

Donation of Valuable Books.—As will be seen by the Secretary's report of the Sept. meeting of the Institute, an exceedingly valuable donation of books has been made to the Library by Henry Seybert, Esq. The list in all numbers over 500 works, mostly on chemistry and subjects relating thereto, and forms a valuable addition, greatly adding to the completeness of the Library in essential books of reference. These books formed a portion of the professional collection of the late Dr. Adam Seybert, the father of the donor, and their present deposition will continue their usefulness as an entire collection to succeeding generations. In the changes which years bring in families, it frequently happens that accumulations of technical books of the highest estimation and immediate value to the collector or, generally, to professional men, become of lesser importance to those who remain; and if such collections can be placed where their utility will be demonstrated, as this one has been, they become a memorial of the attainments of a life-time, and at the same time, they continue to be available in the promotion of those interests of science to which they were originally dedicated. This particular selection of books is remarkable from its variety and value, and the acquisition is highly appreciated, as is testified by the thanks of the Institute to Henry Seybert, Esq.

Book Notices.

NOTES ON BUILDING CONSTRUCTION, PART. II. Commencement of second stage or advanced course, arranged to meet the requirements of the Syllabus of the Science and Art Department of the Committee of Council on Education, South Kensington. 8vo, pp. 236. Rivington, London, Oxford and Cambridge. For sale by J. B. Lippincott & Co.

Part I of this work was favorably noticed in the JOURNAL, vol. C, p. 24. This second part is chaptered and paged in sequence with the first part, so that the two parts will together form one volume. In the notice of Part I the reviewer made some exception to it, as exhibiting details of building construction not always of the most approved modern designs or according to the best practice *in this country* but still it was recommended to readers or students as containing in interesting form much useful and important information. This second part goes over little new ground, but simply essays to add further knowledge of details to what had been previously presented under the same head. Most of its contents should properly have been given, if the building processes were to have been shown in relative completeness, in connection with the former part. Admitting the incompleteness of the

first description, the second one would have supplied, at least in part, the deficiencies, although the arrangement of the subjects would be somewhat confused by the supplementary information for chapter I, appearing as chapter XIII. But the defects noticed in Part I in its failure to exhibit modern or even workmanlike practice are exaggerated in Part II. It is desirable that such a book should as a book of reference or of study be above the implication of being useful only to those who know better than to trust to it.

Exceptions here and there to a statement of general or particular character, a failure to exhibit the several methods of manipulation in workmanship, or the choice of possibly not the best method out of several, and the omission of others, might be admissible in a book of this kind; but the preponderance of mistaken information or even its frequency is seriously derogatory to the usefulness of a technical book. As it is, in this second part of notes on building construction, there is scarcely a description of any procedure in building which can be allowed to pass without some objection or qualification.

Take the first subject treated upon: "Brickwork and Masonry." "Compound Walls."

The section of face-brickwork. The uniform practice of face-brickwork to-day, both in this country and in England, is to show a face of stretchers on the entire face front. For heavy warehouses or similar buildings a Flemish bond of alternate header and stretcher is sometimes adopted, and a wall of no great strength results from the intimate connection of the close-jointed front with the full-jointed back work. Such a wall generally bulges out ¼ to ½ an inch between the floors of the several stories.

The practical bond of the face with the back of the wall for the usual stretcher front is a *dog-tooth* bond course, every five or seven courses. This is effected by clipping the back corner of the face bricks at both ends—allowing the faces to show as whole stetchers—and laying a course of diagonal bricks (headers) in the back wall, the projecting corners of which lock into the face work. Now this face-brick work is not a sham as might be implied; it is a necessity of economical construction. The body of the wall is built of comparatively inexpensive material—of common bricks and mortar—stability of structure has called for twice or thrice the thickness of wall as compared with its height over what was required to sustain the mere weight of the building. Under these conditions the use of a skin of face-bricks—bricks made with extra care, of extra solidity, laid with the thinnest of joints—the whole comparatively impervious to moisture, becomes a legitimate application of materials.

The notes on splays for window jambs and bonds in corners exhibit a complete want of knowledge of what constitutes good workmanship and are specially calculated to mislead a student. In the splays there is not the slightest objection to having some of the joints at the angles, if these joints are locked or overlaid by a brick with a clipped head on the next course or come within two or three courses; while in the

angles of outside or show brick work, overlapping ends will make bond enough to admit a clipped stretcher next to them if necessary, without use of notched bricks.

The notes on brick arches are not only bad in methods exhibited, but although some qualifications are made in the text, yet they are likely to mislead the student on the subject. Half-brick rings in arches are *never good*, neither are double rings of any number of bricks. Heavy brick arches can only be trusted when built as voussoirs—separate blocks of close laid, cut bonded bricks—except, possibly, by use of hydraulic cement, whose tenacity so approximates to the strength of the bricks that the arch becomes a concrete mass.

Hoop iron band is discussed, and every precaution described to render it ineffective. Hoop iron laid in mortar will *not* rust or decompose. A film of oxide of iron with a silicate of lime may form on the surface of the hoop, but after that the rusting ceases. A piece of hoop iron No. 20 to 22, laid in a joint three feet long, will, after the mortar has well set, part before it can be drawn out. Hoop iron ought not to be heavier than No. 20, so that the brick-mason can cut it with his trowel, and so that it will lay flat in a joint. It should *not* be "tarred, sanded," or otherwise precluded from contact with the mortar. It should *not* be "bent up into joints."

Chimney withes may be built as described, but good work everywhere does not follow such practice. A Flemish bond each third or fifth course with stretchers for the rest is good work.

So much room has been taken in noticing the brick work only. Roofs, Joinery, Stairs, Riveting, Fire-proof Floors, Iron Roofs, Plastering, etc., follow. Of these "notes on building construction," the only thing to be said is that the information given is unreliable in degree; and it would be possible to discuss all or any of them, and exhibit the same deficiency of accurate knowledge. Not only is the information unreliable, but it is incomplete; and for a text book or a hand book incompleteness which is not constantly set forth may be even more dangerous than error.

The work purports to deal with methods and ways of construction, but the attempt at separation of these details for the purposes to which they are supposed to be applied—the establishing an entire distinction between how to do anything and why it is to be done at all—is certain to produce disastrous results. The object which the pupil should have in acquiring the knowledge of how the skilled workman, in the several occupations of building, performs his tasks, what are his materials of work, is that such knowledge shall be available in his practice as a constructor at some subsequent time. If it is pleaded that the pupil is supposed to have acquired, or to be in the act of acquiring, the knowledge of the strength of materials—of the theory of construction—as a supplement to these studies, then there should have been an acknowledgment in the commencement of the Work that it is but a partial view, and *each paragraph* should

have stated where the essential complementary information was to be found. As the two parts now stand, it may be asserted that the student in the advanced course of the Science and Art Department at South Kensington will have much to unlearn, as well as much more to learn, before he becomes proficient as a builder.

THE NEW ENCYCLOPEDIA OF CHEMISTRY. Lippincott & Co., Phila., 1876. Issued in 40 parts (Parts XI to XV now received), at 50 cents each.

The five parts in continuation of those previously noticed (Vol. CI, p. 392), fully sustain the character then given to this new Encyclopedia. Since the time of the original work of Muspratt, no book on chemistry applied to the arts of equal value to this has been published. The practical character of the first book, in exhibiting processes in actual use at the time in the fullest degree, has been maintained in the present work; so that it will become at once an almost indispensable source of reference to the manufacturer or chemist. It should be recognized in chemical processes, as in mechanical ones, change, both of method and of product, is of constant occurrence, so that a description of the best methods or most desirable products of to-day would omit a large portion of a book like this; but, on the other hand, a full record of what was once the best method or product, if much more voluminous, possesses in its extent alone a higher value for other applications than the restricted practice of the moment will afford. All the chemical processes which once gave good results, although they may now be disused, should be considered and weighed in the advancing steps towards new accomplishments. This Encyclopedia of Chemistry, of 1876, is a fifty years' compendium of applied chemistry, as complete as could possibly be expected to the date of its issue.

Cornish Pumping Engines.—From *The Mining Journal*, Sept 9th, 1876.—The number of pumping engines reported for July is 29. They have consumed 2177 tons of coal, and lifted 16,200,000 tons of water 10 fms. high. The average duty of the whole is, therefore, 50,100,000 lbs. lifted 1 ft. high, by the consumption of 112 lbs. of coal. The following engines have exceeded the average duty:

Crenver and Wheal Abraham—Stuart's 90 in.	Millions	55·1
do. do. —Willyam's 70 in.		61·9
West Basset—Thomas' 60 in.		50 2
West Tolgus—Richard's 70 in.		61·7
do. —Taylor's 60 in.		51·3
West Wheal Seton—Harvey's 85 in.		66·2
do —Rule's 70 in.		60·5
Wheal Unity Wood—70 in.		70·0

Civil and Mechanical Engineering.

ISOCHRONOUS GOVERNORS.

By A. K. Mansfield.

The office of a governor or regulator is to prevent deviation from a constant, uniform velocity of the machine governed, within certain limits. That no governor can retain this velocity absolutely constant is generally understood, from the fact that all governors are first called into action after a change of velocity has taken place. The amount of change required to call the governor into action is a measure of its *sensitiveness*. The governor having begun to act, it is in most cases desirable that it should prevent further change of velocity; also that it should restore the *true normal velocity*, and that as quickly as possible. That most governors now used fail to perform these offices as well or as quickly as may be, will appear from the following discussion, which treats, however, of centrifugal governors only, since the majority of governors in use are of this kind, and since this may be considered the type of governors in general.

Fig. 1 is a diagram of a Porter governor, which differs from the ordinary Watt's governor, or revolving pendulum, in having a heavy weight attached to the lower ends of the links. Let G represent the weight of one of the balls, G' the additional weight, l the length of an arm from the point of suspension to the centre of gravity of the ball, l' the length of a link, also of that portion of an arm intercepted by the link, a the distance from the axis to the point of suspension of an arm, also to the points of support of the weight G', α the angle of an arm, also of a link with the axis, and C the centrifugal force of one of the balls when the angular velocity is w. If the governor is in equilibrium, the resultant moment of the forces C, G and $\frac{1}{2}G'$, about the point of suspension, is equal to zero. The moment of C is $Cl\cos\alpha$, of G, $-Gl\sin\alpha$, and of $\frac{1}{2}G'$, $-\frac{1}{2}G'\dfrac{l'\cos(90-2\alpha)}{\cos\alpha}$, being the com-

ponent in the direction of the link of the vertical force $\frac{1}{2} G'$ times the perpendicular distance of the link from the point of suspension. We have, therefore,

$$C l \cos a - G l \sin a - \tfrac{1}{2} G' \frac{l' \cos (90 - 2a)}{\cos a} = 0,$$

or, since from mechanics $C = M w^2 r = G \frac{w^2}{g} (l \sin + a)$, (where g = gravity); and $\cos (90 - 2a) = \sin 2a = 2 \sin a \cos a$, we have by substitution, and after dividing both members by $G l \sin a$,

$$\frac{w^2}{g} (l \cos a + a \cot a) = 1 + \frac{G' l'}{G l}.$$

But the quantity in parentheses is the vertical distance of the balls from the intersection of the arm produced, with the axis, which distance we will call h. Writing this in the form of an equation, we have

$$h = l \cos a + a \cot a \quad . \quad . \quad . \quad . \quad (I)$$

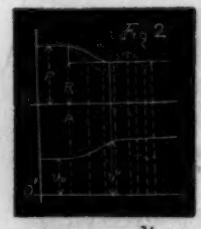
and substituting in above

$$w^2 = \frac{g}{h} \left(1 + \frac{G' l'}{G l}\right) \quad . \quad . \quad . \quad . \quad (II)$$

This is the equation of equilibrium of the Porter governor. If $G' = 0$, this becomes $w^2 = \frac{g}{h}$, which is the corresponding equation of the Watts governor.

These equations show that different values of h correspond to different values of w; therefore, if the governor is so constructed that h remains constant for all positions of the balls, w will also be constant, and the governor is *isochronous*.

The action of isochronous and non-isochronous governors is shown graphically by Fig. 2. We suppose the governor in each case to be



direct acting, that is, that the vertical movements of the balls are communicated directly to the valve or other regulating apparatus. O is the origin of co-ordinates of the curves of force P and resistance R, acting on any point of the machine designed to move uniformly; and O' is the origin for the curve of velocity of the same point. Horizontal co-ordinates are distances traversed by the point. Suppose the point to have moved uniformly from O to A at its normal velocity v_0, and at A the resistance to be suddenly decreased to R_1. Then, on account of the accelerating force $P - R_1$, the velocity begins to increase, the balls of the governor to rise, the valve to close, and P to de-

crease. This continues until P is reduced to R_1, when the velocity has reached its maximum v_1, and, if the governor is not isochronous, the machine continues to move uniformly at this velocity. If, however, the governor is isochronous, the balls can be in equilibrium at only one velocity v_0; therefore, after P is reduced to R_1, since the velocity is greater than v_0, the balls continue to rise, the valve to close, and P becomes still less, until, on account of the retarding force $R_1—P$, the velocity is again reduced to v_0, when the balls are at their highest position.

Since P is now less than R_1, the velocity continues to decrease, the balls begin to fall, the valve to open, and P to increase. In this way a series of vibrations of velocity on each side of v_0, and of force on each side of R_1, take place, until the normal, uniform velocity is restored. Unless the governor is isochronous, therefore, it does not restore the normal velocity, but only prevents its increase or decrease beyond certain limits, depending on the variations of resistance in the machine.

The maximum change of velocity following any given change of resistance, is also less with the isochronous than with the non-isochronous governor; for in the former case a slight change of velocity causes the balls to move continually farther from their first position, until equilibrium between P and R is restored; while in the latter case a slight change of velocity corresponds to only a slight change in the position of the balls, and, therefore, of the valve.

As before stated, if h is constant for every position of the balls, the governor is isochronous. To make h constant the balls must be guided in a curve, not an arc of a circle, which may be called the curve of isochronism. In case $G' = 0$ this curve is a parabola, but, otherwise, it is a curve having a complicated equation, the co-ordinates of which are a combination of those of a parabola and a circle. To guide the balls in either of these curves necessitates complicated mechanism, which makes the construction impractical. The points of suspension and length of arms may, however, be so chosen that the arcs of circles in which the balls move vertically shall more nearly coincide with the curve of isochronism, than is the case in the ordinary construction of Fig. 1. The best approximation of this kind is made by choosing the length and middle position of the arms, to coincide with the radius of curvature of the curve of isochronism at that point. In this case the points of suspension would be on opposite sides of the axis from the balls, which makes it necessary to

cross the arms. A more convenient construction is that of Dr. R. Pröll,* in which, crossing the arms is obviated by attaching the balls to the links produced beyond their intersections with the arms.

The approximately isochronous construction is, without doubt, the best for *indirect acting* governors, or those which, when the balls are not in their middle position, permit some other mechanism to act on the valve, etc. On account of the lost motion caused by imperfect fitting of the links and levers, which transmit the vertical movements of the balls, their middle position is not absolutely fixed. Within the limits of this lost motion, the governor should be isochronous. This is the case with a well constructed approximately isochronous governor, which for a short distance each side of the actual middle position is, practically, isochronous, but beyond this is non-isochronous.

The advantage of this construction, when indirect acting, over the truly isochronous, will be seen from the following:

The dotted curves of Fig. 2, which illustrate the action of a direct acting isochronous governor, show also the action of indirect acting governors in general. If, however, the indirect acting governor is isochronous, the balls continue to rise after the driving force has been reduced to R_1; or, as long as the velocity is greater than the normal, and reach their highest position when the velocity is again equal to the normal. The action on the valve is, therefore, greatest at this point. In the non-isochronous governor the balls reach their highest position when the velocity is a maximum, and the action on the valve is, as it should be, greatest at the point. It will be seen from this that the approximately isochronous governor combines the advantages of both the other classes when it acts indirectly, but, as shown above, the truly isochronous construction is to be preferred when acting directly.

A truly isochronous governor has been invented by Prof. Rankine,† in which, in place of making h constant, l' (the distance from point of suspension to point of connection of the arm with the link) is made to vary in such a way as to counteract the variation of h. An objection to this arrangement is the resistance to motion, and consequent lack of sensitiveness, caused by the sliding collars at the ends of the links.

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* For a complete discussion of the theory of this ingenious governor, see "Der Civilingenieur," Frieberg, 1872.

† See Rankine's "Mills and Mill-work," § 363.

Still a third method of making centrifugal governors isochronous, is to make G' vary in such a way that it shall, in connection with the weight of the balls, just balance the centrifugal force due to the normal velocity at every position of the balls. This method, invented by the writer, only necessitates a slight alteration of the ordinary non-isochronous construction. It is an approximate method in which, however, the approximation may be made as close as desired. It has, therefore, the advantages of truly and of approximately isochronous governors.

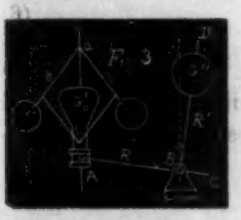


Fig. 3 represents one form of this construction. It consists of an ordinary Porter governor, having the usual lever $A\ B\ C$ to transmit the vertical movements of the balls. This lever has an additional arm $B\ D$, carrying the weight G''. If R represents the length of the arm $A\ B$, R' that of $B\ D$, B the angle between these arms, β the angle between $A\ B$ and the vertical, and F the vertical force at A due to the weight G'', then

$$F = \frac{G''\ R'\sin(B-\beta)}{R\sin\beta} = \frac{G''\ R'}{R}\sin B\,(\cot\beta - \cot B) \quad . \quad . \quad (1)$$

To make the governor isochronous, this force must be equal at every position of the balls, to the difference between the actual weight G' and the value that this weight should have at the normal velocity, as found from eq. II; in other words, the resultant of G' and F should vary in such a way as to make the second member of eq. II constant.

G' is the weight corresponding to the height h. If we represent by G'_0 the actual weight, corresponding to the height h^0, of the balls in any particular position, then $G'_0 - G'$ is the value that F should have to make the velocity the same for any other position. Solving eq. II for G', and especially for G'_0, and taking the difference of the equations thus found, we have

$$G'_0 - G' = G\,\frac{l\,w^2}{l'\,g}\,(h_0 - h) \quad . \quad . \quad . \quad (2)$$

Noticing the value of the variable h in eq. I, it will be seen that eq. (2) does not vary in the same manner as eq. (1); therefore, F cannot be equal to $G'_0 - G'$ in every position. The best approximation will be made by putting $F = G'_0 - G'$, and $d\,F = d\,(G'_0 - G')$ at the middle position. This gives the following equations:

$$G'' \frac{R'}{R} \sin B (\cot \beta - \cot B) = G \frac{l}{l'} \frac{w^2}{g} (h_0 - h) \quad . \quad (3)$$

$$G'' \frac{R'}{R} \frac{\sin B}{\sin^2 \beta} d\beta = G \frac{l}{l'} \frac{w^2}{g} dh \quad . \quad . \quad . \quad (4)$$

Dividing eq. (3) by eq. (4), and assuming $\beta = 90^0$, and $h = h_1$ at the middle position, we have

$$\cot B = -(h_0 - h_1) \frac{d\beta}{dh} \quad . \quad . \quad . \quad (5)$$

and from eq. (4)

$$G'' = \frac{G\ l\ R\ w^2}{g\ l'\ R' \sin B} \cdot \frac{dh}{d\beta} \quad . \quad . \quad . \quad (6)$$

Since the vertical movements of the end A of the arm $A\ B$ are twice as great as those of the connecting points of the links and arms, therefore the relation between the angles α and β may be expressed as follows:

$$d(R \cos \beta) = -2\, d(l' \cos \alpha),$$

from which

$$d\beta = -\frac{2\, l' \sin \alpha\, d\alpha}{R \sin \beta},$$

and from eq. I

$$dh = -l \sin \alpha\, d\alpha - \frac{a\, d\alpha}{\sin^2 \alpha}.$$

Substituting these values in equations (5) and (6), remembering that for the middle position $\sin \beta = 1$, and $\alpha = \alpha_1$, these equations become

$$\cot B = -(h_0 - h_1) \frac{2\, l' \sin^3 \alpha_1}{R(l \sin^3 \alpha_1 + a} \quad . \quad (III)$$

and

$$G'' = \frac{G\ l\ R^2\ w^2 (l \sin^3 \alpha_1 + a)}{2\, g\ l'^2\ R' \sin B\ \sin^3 \alpha} \quad . \quad . \quad . \quad (IV)$$

We will now distinguish three methods of applying the weight G'', viz., so that the force F is zero (1) near the upper, (2) at the middle, and (3) near the lower position of the balls. In each of the cases we will assume $a = 0$, or the upper and lower joints of the governor to be in the axis, and $\beta = 90°$ for the middle position. The equations for the solution of these cases then become as follows:

$$h = l \cos \alpha \quad . \quad . \quad . \quad . \quad . \quad . \quad (I^a)$$

$$G'_0 = G \frac{l}{l'} \left(\frac{w^2 h_0}{g} - 1 \right) \quad . \quad . \quad . \quad (II^a)$$

$$\text{Cot } B = -(h_0 - h_1)\frac{2\,l'}{R\,l} \quad . \quad . \quad . \quad \text{(III}^a\text{)}$$

$$G'' = \frac{G}{g}\left(\frac{l}{l'}\right)^2 \frac{R^2\,w^2}{2\,R' \sin B} \quad . \quad . \quad . \quad \text{(IV}^a\text{)}$$

The quantity h_0 is that value of h corresponding to the upper, middle or lower position, according as the equations are applied to the 1st, 2d or 3d cases, while h_1 is in all cases the height corresponding to the middle position.

The conditions to be fulfilled to make F vary as $G'_0 - G'$ are expressed in eq. (4). If the above values of $d\,\beta$ and $d\,h$, for the case $a = 0$, be substituted in this equation, it will be found that the requirement is that $\sin^3 \beta$ be a constant. This will be more nearly fulfilled the less the difference between the maximum and minimum values of β, and this difference will be less the greater R. It will be found that when $R = 1{\cdot}5\ l$ to $2\ l$, which is a convenient length the approximation is very close. Since a, when not zero, is usually small compared with l, the approximation is nearly as close in this case.

Case 1.—The force F acts downward in all positions, and, therefore, assists the weight G'_0. This is perhaps the best arrangement for newly-designed governors for ordinary purposes, since the sum of the weights is least.

Case 2.—Since F is zero at the middle position, this arrangement may be applied to governors already constructed. The necked joint at the point of action of F should be made carefully, to prevent lost motion at that point.

Case 3.—F acts upward in every position. This arrangement has a very unique application in delicate machinery, which may be regulated by the variations of the moment of friction at the point of action of F. The energy required of the governor, or the work to be performed by it, in regulating, is here reduced to a minimum. The fulcrum on which the lever turns, may be a knife edge. The point of action of F has a horizontal motion equal to the versed sine of half the arc traversed by that point; but the arm $A\,B$ may be made so long that this motion, and, therefore, the resistance, at that point will be unappreciable. Also, if the construction is carefully made, so that the balls have equal weight and centrifugal force, and the resultant centrifugal force of G' is zero, there will be no pressure of

that weight against the shaft, and the friction at that point will not be appreciable. We have, then, to consider only the resistance at the four joints of the governor. This resistance is due to the friction caused by the components, in the direction of the links and arms, of the forces C and G. These forces, reduced to the points $b\ b$, become $C\frac{l}{l'}$ and $G\frac{l}{l'}$. Representing the sum of the former components by S, and of the latter by S', we have, as may be seen from Fig. 4,

$$S = \frac{C_0\, l}{2\, l' \sin a} + \frac{G\, l}{2\, l' \cos a},$$

$$S' = \frac{C_0\, l}{2\, l' \sin a} - \frac{G\, l}{2\, l' \cos a}.$$

S represents the pressure on the pivots a, and S' that on the pivots a_1 and $b\ b$. Let ρ be the common radius of the pivots, and f the co-efficient of friction; and let $C - C_0$ be the increase of centrifugal force necessary to move the balls from their position. This force acts with the lever arm h, while the resistance of friction acts with the arm ρ. The angular motion being twice as great at b as at a and a_1, we have

$$(C - C_0)\, h = \rho\, f\, (S + 3\, S'),$$

or $$(M\, w^2\, r - M\, w_0^2\, r)\, h = \rho\, f \left(\frac{2\, M\, w_0^2\, r\, l}{l' \sin a} - \frac{G\, l}{l' \cos a}\right);$$

reducing, this becomes

$$\frac{w_2 - w_0^2}{2\, w_0^2} = \frac{\rho\, f}{2\, l' \sin a \cos a}\left(2 - \frac{g}{w_0^2\, h}\right).$$

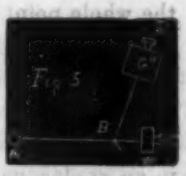
Dividing numerator and denominator of the first member by $w + w_0$, $2\, w_0$ being considered approximately equal to $w + w_0$; and substituting for $w_0^2\, h$ its value from eq. II, and reducing, this becomes

$$\frac{w - w_0}{w_0} = \frac{\rho\, f}{l' \sin 2a}\left[\frac{2G'\, l' + G\, l}{G'\, l' + G\, l}\right]. \qquad (7)$$

The ratio $(w - w_0) : w_0$ is the coefficient of *lack of sensitiveness* of the governor. This equation shows, therefore, that while the sensitiveness is increased by making ρ and f small, it is also increased by making l' and sin $2\, a$ large. Sin $2\, a$ is, however, a maximum when $a = 45°$; therefore this angle is the most favorable for the middle position of the balls. The equation also shows that if G' is infinitely small compared with G, the sensitiveness is twice as great as if G is infinitely small compared with G'. The sensitiveness is therefore

greater the less the ratio G' to G, and is a maximum, as far as G' is concerned, when that quantity is zero. In this construction G'_0, or that value of G' corresponding to the lower position of the balls, may be made very small, except when the variations of resistance to be regulated by the governor are too great. A small value of G' corresponds to a small velocity w, and eq. (4) shows that dF is proportional to w^2; therefore the less G' the greater the changes in the position of the balls to compensate given changes of resistance in the machine.

The quantities ρ and f will be made very small if pointed pivot screws are used at the joints; and where extreme sensitiveness is required, agate bearings may be employed.



The governor may be adjusted in the manner illustrated by Fig. 5. A movable weight W is placed on the arm $B\,C$, the weight being made about heavy enough to balance the lever, without the weight G'', in the middle position. The virtual weight G'' is the entire weight of the lever, and may, therefore, be considered as concentrated at the resultant centre of gravity of the weights G'', W, and the weight of the arms. Moving the weight W on the arm $B\,C$ therefore changes the angle B, which is the adjustment to satisfy eq. III; and moving the weight G'' on the arm $B\,D$ changes R' so as to satisfy eq. IV.

It is thought that this governor may, in some cases, take the place of the ordinary pendulum with advantage, for variations in the resistance of the atmosphere cannot affect its correct action, variations of temperature can affect it but little, and it may be made almost absolutely isochronous.

Fracture of Fly-Wheel.—The London *Engineer* states that recently a fly-wheel three tons weight, nine feet in diameter, cast in one piece, having worked for years as part of a steam engine, was laid horizontally on two balks of timber in the yard of the West Hartlepool cement works, Eng.; the wheel was left perfect at night, and was found next morning fractured in several places, no person having touched it. The day previous the sun's rays had heated the rim considerably, and the night being cold, the arms having retained but little heat, contracted too rapidly, snapping from the boss and rim of the wheel.

THE MANUFACTURE OF STEEL AND MODE OF WORKING IT.

By D. Chernoff, Assistant Manager of the Abouchoff Cast Steel Works, near St. Petersburg. Translated by W. Anderson, M. Inst. C.E.

Communication to the Russian Technical Society, 1868.

[From *The Engineer*, July 7th, 1876.]

[Continued from Vol. cii, page 186.]

From what has been said above, you must have perceived that the whole point lies in the structure of the steel, and that for successful forging, the heated ingot, after it is taken out of the furnace, must be forged as quickly as possible, so as to leave no spot untouched by the hammer, no spot in which the steel might crystallize quietly, because, as I have said, the heated piece of steel must be considered in an analogous condition to a saturated solution of strongly crystallizing salt, which, the moment it is allowed to cool quietly developes large crystals. I repeat that this has reference to temperatures higher than *b*.

To show you how great is the tendency to crystallization in steel heated up to a high temperature, and allowed to cool quietly, even for a short time, I have brought some specimens by which you can judge of this tendency. The larger specimen was obtained under the following circumstances: An ingot of soft steel prepared for forging was allowed to remain in the furnace for half an hour after it had been heated to a bright orange heat, because the hammer was occupied by another forging. But, in order not to overheat the ingot, the smith reduced the temperature of the furnace, and gradually let down that of the work to a bright red. If you will now call to mind what I have said about the tendency of steel to crystallize in cooling between the temperatures *c* and *b*, you will readily believe that during this half hour the ingot had time to change its internal structure from the amorphous to the crystalline, a change which was greatly assisted by the extreme softening it had undergone at the higher temperature, which presented favorable conditions for the movements of the particles within the mass. As soon as the hammer was at liberty, the ingot was taken out of the furnace, and placed on the anvil; with the very first blow on its middle, the end

of the ingot tumbled off from the effects of the concussion; the form of the fracture you can see on the first specimen before you. The remaining samples are taken from other ingots under similar circumstances, and they all show how strongly the crystals have developed themselves; and, moreover, each crystal seems to have formed itself in an independent manner, with so little cohesion to the neighboring crystals that one shock was sufficient to separate them, and allow the overhanging piece to detach itself by its own weight. The specimens show that fracture has taken place only along the surfaces of the crystals, and nowhere through the body of them.

It might be concluded from the incident above described that the ingot was completely spoiled, and could not be forged again. But such a conclusion would be quite erroneous. It is true that the higher the temperature of the steel, the more susceptible is it to the action of the furnace gases, and the quicker it changes its chemical condition, so that if kept to a high temperature in the furnace it will gradually lose its carbon and be slowly converted into iron, burning. The example I have cited, however, is only a case of overheating; and in order to know how to correct the mistake made, we must turn to the conditions of crystallization.

Let us, again, take the beaker of melted alum. Suppose the melting point to be t_o, and that the solution was further heated up to t_i under which operation it would continue liquid. Let the temperature fall gradually, keeping the solution perfectly quiet, then we shall find that at some temperature t between t and t_i the salt will begin to crystallize; but it is only necessary to shake up the solution to make the crystals dissolve again at the same temperature t. We shall notice, also, that there is scarcely any cohesion between the separate crystals so formed, and if we do not wish to disturb their mutual relations, we shall have to allow the crystallizing solution to cool below the temperature t_o, and then by a second heating up to t_o we should again receive a fluid mass. The same result would be obtained by a simple single increase of temperature; the difference lies in this, that the liquid produced from the destruction of the incipient crystals in the three cases stated has three distinct temperatures. Applying this reasoning to steel, it is easy to see that, in the case cited, the temperature of the ingot should have been raised again before forging, so as to impart to it an amorphous structure; it should then have been quickly and unceas-

ingly forged all over its extent, while the temperature was lowering somewhat, and the tendency to crystallization decreasing. Or the particles that had commenced to crystallize might have been brought into a motion corresponding to the shaking of the beaker, but very carefully, so that the crystals formed should not fall to pieces, in other words, hammered with the very lightest blows; and the temperature being higher than *b*, the crystals would have run into each other, the ingot would have assumed the amorphous condition, after which it might have been worked like a piece of wax. It is, of course, better under such circumstances to allow the overheated ingot to cool quietly, then to heat it again, taking care not to allow the temperature to rise too high and give the mass an opportunity of again changing the restored amorphous condition to a crystallized one; the forging will then not require any special precautions, and the ingot will not tumble to pieces. I now present you with one of many instances of the spoiling of large steel ingots from the causes I have been explaining, and proceeding from a thorough ignorance, on our part, of the material with which we are working.

On cutting off of the end of a shaft 25 in. diameter, the shake *a b* was met with in the position indicated on the sketch. The dotted lines show the form of the forging before the neck was turned. The walls of the cavity were lined with large well-developed crystals, the size of some of which—as you may see by the specimen before you—reached half an inch, and between the large crystals were interposed smaller ones about one-tenth of an inch diameter; the crystals projected only half their height into the cavity, and on breaking the sample at right angles to the crystalline surface, the prolongation of the crystals into the mass of steel could not be traced; the fracture, though crystalline, was of a totally different nature from that forming the surface of the cavity, and similar to that of the mass of the ingot in the same neighborhood. The surface of the wall of the cavity had a clear unoxidized metallic appearance, with a silvery lustre, as you see by the specimen. The ingot out of which this shaft was forged was overheated in the manner I have described, and taken out of the furnace when the crystals had already begun to form. At the first blows of the hammer on its end the part *c* which received the full force of the blow was separated from

the mass on account of the want of cohesion caused by the crystallization, and formed the internal inclined plane *a b*; and as the forging proceeded, the outer layers, being more acted on by the blows, were more extended, and the cavity considerably increased. The fact that on striking the end of an ingot the force of the blow is taken up by the wedge-shaped piece *c* may be easily demonstrated to the eye, because in those places where swelling, compression, or tension follows the blows of a hammer, a dark shade is soon produced by the partial detachment of thin plates of scale. The same result will be arrived at by an analytical investigation of the effect of a blow on *c*. The appearance of the crystallized surface of the specimen is, as you see, completely analogous to that of every other specimen of overheated steel; the difference lies only in this, that the surface is not oxidized because the air could not penetrate into the cavity while the shaft was in a heated state.

It is worthy of remark that if a piece of steel be so greatly overheated as to assume a strongly crystalline structure, and become liable to destruction at the least shock, and is allowed to cool quietly; then the separate crystals, if they have not been separated by external forces while in a heated state, become so joined or grown together that the fracture of the cold piece takes place, not along the surfaces of the separate crystals, but indifferently through their mass, though the junctions of the fractures of individual crystals generally take place along their planes of adhesion, owing to which, such fracture is always very sparkling. From this it is evident that the close contact of two surfaces of metals of the same nature heated to a higher temperature than *b* is sufficient to produce union. This is, in fact, welding; and if, in welding, hammering is always necessary, it is only because, in the first place, it is very difficult, without hammering, to press two pieces one against the other; and, secondly, that it is otherwise difficult to free the surfaces to be welded from the slag which alone protects them from oxidation during the heat. Of course the more homogeneous or analogous the structure of the two pieces the more perfect will be the union; but one of the first conditions is that there should be the fullest contact between the unoxidized metallic surfaces.

Up to the present we have been discussing the forging of steel only at temperatures higher than the point *b*, and we have stated that the aim of the forge-master must be to change the form of his ingot in

such manner as to keep all its particles in constant motion, and so hinder the formation of crystals, which materially lower the tenacity of the steel. Let us now see what circumstances arise in forging below the temperature *b*. The fracture of a piece of cast steel presents a rough surface consisting of groups, as it were, of crystalline *débris*—so-called grains—piled one on another, and generally of a very irregular form. Under the microscope it is easy to see considerable interstices between the groups of grains, and, on more minute examination, spaces may be observed between the grains themselves, which form with each other various interlacings and combinations. In a word, steel, under the microscope, has a more or less porous structure, at first sight, destructive of any belief in the tenacity ascribed to it. Time will not permit me to enter into details relating to the appearance, size, and arrangement of the grains; it answers my purpose simply to direct attention to the fact that among the grains of steel there are numerous vacant spaces—pores. The question arises—what becomes of these pores when the steel, being heated up to the temperature *b*, acquires the amorphous condition? In all probability, during the rise of temperature from *o* to *b*, the expansion of each individual grain, formerly in itself a compact body, goes on incomparably faster than the increase of the external dimensions of the piece of steel, so that the period at which it assumes the amorphous condition coincides with the moment when the atoms composing the individual grains, moving away from each other under the influence of heat, fill up these spaces; it is, therefore, conceivable why steel becomes at this stage incompressible—why it is impossible to increase its density by hammering, no matter how heavy the blow may be.

It is evident, from the above reasoning, that if we wish to increase the density of steel, to approach its component grains to each other and so bring them to a more energetic cohesion, we must do so when not opposed by the force of heat, that is only at temperatures below the point *b*. Thus, forging at temperatures below the amorphous condition has the important advantages we are in the habit of ascribing to it. We never forge large ingots below the temperature of amorphous structure, and guns never were and never are forged below that point, because for gun steel, the temperature of amorphous structure lies, as I have already stated, at a dull red heat, that is, within limits below which, we can produce no effect on large steel masses, with the mechanical means at our disposal. It

would be necessary to forge small ingots under our largest hammers, and what an exhibition of inadequate mechanical appliances would be presented if a 4-pounder gun were forged under a 35 ton hammer! The practice now is to forge the 4-pounders under the 3-ton, and sometimes the 5-ton hammer, while the 35-ton hammer is used for the 6 in., 8 in., and 9 in. guns, in which the diameter of the cast ingot reaches up to 40 in.; but if you picture to yourself such a large mass of steel heated to a non-sparkling red heat, you will perceive that the utmost efforts of the heaviest hammer will remain inoperative—it would be impossible to forge it. Forging is carried on at points below the amorphous condition, but it is only in very small pieces, and by those who have some knowledge of the influence of heat on steel.

Fig. 1.—Crystals taken from the sides of a cavity in steel ingot formed by contraction—magnified 275 times.

Fig. 2.—Groups of crystals taken from the sides of a cavity formed by contraction in a cast steel ingot—magnified 275 times.

If a cast ingot of any given structure is heated not higher than the point *b*, then in its heated state it will retain its structure. If it was crystalline, then in a heated state it would be composed of the same crystals, which, however, would be considerably softened. If the piece of steel be forged in this condition, then its crystals or grains, being driven against each other, will change their shapes, becoming elongated in one direction and contracted in another, and the increase of density becomes so considerable that I have found the specific gravity rise as high as eight, which I have never yet found in steel forged at temperatures higher than *b*. This comparatively cold forging communicates to the metal great clearness of ring, it is no longer so easily worked with the file, weak sulphuric acid produces hardly any effect on it, and so on. With regard to its absolute tensile strength, I regret very much that I have been unable to make any experiments; but there can be no doubt that it is very high. The fracture of such

Appearance of a transparent substance that crystallizes in six-sides plates on the surface of cavities formed by contraction in steel ingots—magnified 82 times.

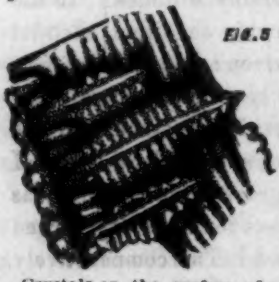
steel has a silky lustre, and under the microscope it is very difficult to trace the limits of the individual grains; they present the appearance of waxy little balls squeezed together under a powerful press. If you cut off and polish the surface of a piece of steel so treated, and then immerse it in weak sulphuric acid, after a time a pattern will form on the surface, which presents the appearance of an irregular interlacing of crooked lines, the size of the network depending on the original size of the crystals, the manner of forging, and so on. I have already stated that the tendency to crystallization, as well as the form of the crystals and their relative positions, depends on the purity of the steel, and the conditions under which the cast ingots are poured and cooled. In the higher qualities of boulat, the tracery developed by acid is of remarkable beauty and regularity.

The cause of the patterns appearing is the various groupings of the crystals during their formation. These crystals have not the same chemical composition; the lighter parts of the tracery contain much more carbon than the darker parts —a fact which I have demonstrated—and consequently, simultaneously with the grouping of the crystals or grains, there is a segregation of like chemical compounds. If you heat the piece of steel thus marked—damascened—up to the temperature *b*, or a little higher, and allow it to cool again, you will no longer be able to obtain any pattern by the action of acids. From what has been already said, the cause of this must be quite plain, and I need not dwell on it any longer. In conclusion, I will show in what manner the properties of a cast steel ingot may be best taken advantage of. With respect to forging at temperatures below the amorphous condition, we can only, as I have already stated, make the smallest guns under the largest hammers. We have at present no mechanism capable of dealing with large masses at low temperatures; but if it were possible, there can

FIG. 4

Arborescent growth on the sides of cavity formed by gas on contraction in cast steel ingot—magnified 80 times.

FIG. 5



Crystals on the surface of a contraction cavity in the heart of a 72 lb. cast steel ingot—magnified 82 times.

be no doubt that guns so forged would be of the very best quality, and their reception into the service would be facilitated by the appearance of the patterns brought out by weak acids, because of the close connection which exists between the quality and the appearance of the steel so treated.

FIG. 8

Insoluble substance remaining after dissolving steel in nitric acid—magnified 77 times.

FIG. 9

Two grains from the fracture of an ingot of cast steel 1 in. forged diameter of 0·027 in.—Magnified 150 times.

To adapt ourselves to the means possessed by our steel works, we must strive to obtain our material as much as possible of a fine-gained structure; and with this view it is necessary, as we have already seen, to heat the ingots to a high temperature, and to keep forging them until they cool down below the temperature *b*, because, by so doing, we shall be giving the work the required form, and at the same time prevent its structure becoming crystalline, but rather make it approach the amorphous condition. But if we examine the circumstances attending the practical application of this rule to the forging of ingots intended for heavy guns, we shall find that, in many cases, it will be impossible to carry it out, and a forging will be obtained, the structure of which is far from uniform, and more likely to be coarse crystalline than fine-grained. We shall attain our object more easily, and with more certainty, if after having given the forging the desired shape, we alter its structure to the homogeneous amorphous condition by heating it, and then fix that condition by rapid cooling to a temperature lower than *b*. For this purpose, it is of course necessary to surround the ingot after heating by some rapidly cooling medium.

From what has been said above, it is evident that, with the same rate of cooling, we shall fix the amorphous condition of the steel with the greatest certainty when we exceed the temperature *b* as little as possible; and for that reason it is well to determine that temperature for each ingot beforehand. Having, therefore, heated the finished forging, or better still, the rough turned and bored gun, to a temperature somewhat higher than *b*—a point which ought to be determined by the pyrometer—let it then be plunged as quickly as possible into the cooling medium, be it water, oil, or what not, and having reduced

the temperature of the work to below the point *b*, allow it to finish cooling gradually, so as to prevent, as far as possible, internal strains due to sudden and unequal contraction. To show you what changes may be produced in the structure of steel by the operations described, I lay before you three specimens. They are all broken from the same piece of steel. The first specimen exhibits the coarsely crystalline, porous structure that characterized the ingot, notwithstanding that it was well worked under the 35-ton hammer. The second sample was heated to a little above a bright red non-sparkling heat, and then allowed to cool in the open air. Comparing the fractures of these two pieces, you perceive the structure is totally different, though offering one surface to the other proves by the fit that the two pieces were at one time united, and that neither piece has been touched by the hammer since they were broken asunder. The third fragment of the same piece was heated to a bright red heat, and then quickly plunged into water, and left till the temperature sank to a reddish-brown heat; it was then taken out and allowed to cool in the open air. The fracture shows that on the external surfaces, for a depth of 0·1 in. the amorphous condition has been completely preserved. In the centre of the piece the mean diameter of the grains, as measured by the microscope, is 0·0004 in., while the mean diameter in the first piece was 0·15 in., and in the second 0·005 in. To this I may add that to break the first piece one blow of a hand-hammer was sufficient, to break the second required five such blows, and the third piece had to be broken under a steam-hammer, because the strength of the smith was inadequate for the work.

A similar experiment was made with the tire of a railway wagon wheel. A piece of an ordinary tire was broken by a 5-ton hammer into three pieces. One of them was heated to a light red, and then thrown on the floor to cool in the open air to the ordinary temperature. It was then put under the 5-ton hammer, and required four heavy blows to break it, whereas the first piece broke under one blow of the same hammer. The third piece I heated to a bright red heat, plunged it quickly into water, and took it out again when cooled to a reddish-brown heat, and then found that it required five heavy blows of the 5-ton hammer to break it. Therefore, I say, that in order to fix the amorphous condition, and thereby to increase the tenacity of steel, it is necessary to plunge it, after heating, into water. It may be cooled in oil, but, in the first place, this is expensive, and, in the

next, numerous precautions have to be taken to prevent the oil catching fire. With respect to cooling in water, I must add that the conductivity of hot metal is very small, and that although the external visible parts soon show the desired fall of temperature, yet the central portions remain very much hotter; it, therefore, requires care, experience, and many precautions to avoid the too rapid cooling of the outer layers, and the consequent development of severe internal strains. Time will not permit me to treat this subject in greater detail. I can only state my opinion that not only should every gun be subjected to treatment above described, but also every article made of steel, as, for example, tires, axles, shafts, etc.*

It follows, from the principles laid down, that any steel article having, from constant work and concussion, lost its original strength, that is, assumed a crystalline structure, as happens to wagon axles, engine shafts, etc., can, by the help of the process above described, be completely restored by having communicated to it, if not an amorphous structure, at least one so finely grained as to be nearly equal to it, and, at the same time, a compactness and tenacity it very likely did not possess when newly taken into service. I trust that you will now find it easy to understand the circumstances and facts which I brought under your notice at the commencement of this paper. I have heard with pleasure, from a friend just returned from England, that at the Woolwich Arsenal they have adopted the practice of heating their steel gun linings, after forging and rough turning, and plunging them into oil; he was unable to give me any details of the operation, as he only noticed it in passing, but the object of the treatment was, he ascertained, to give the steel greater tenacity. It is possible that I may soon obtain information as to the reasoning which led to the adoption of this practice, and I shall be exceedingly pleased if I find it is based on theories similar to those I have had the honor of laying before you this day. With respect to the doctrines I have been advocating, I have been accused of being too bold in my conclusions, but I am prepared to take a still more decisive step, and to announce the opinion, resulting from my observations, that "future investigation into the question of forging steel will not deviate from the path into which we have this day directed it."

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* 1875. A wagon axle treated in the above manner, and cooled in water, withstood twenty-two blows of ½ ton weight falling 14 ft., and remained unbroken.

APPENDIX.

The following notes of microscopical observations have never yet been published. The drawings annexed were made under the microscope, with the assistance of Hartnack's camera lucida, in the years 1868 and 1869. Figs. 1, 2, and 3 are especially remarkable. They represent the efflorescence appearing in the cavities of hard tool steel, melted in a crucible, and allowed to cool extremely slowly in its furnace. The ingot on cooling exhibited cavities caused by contraction and by bubbles, and these have on their walls or faces arborescent growths, and on the surfaces of these growths I found microscopic crystals, composed of extremely thin transparent plates, having a high refractive power, and extremely hard, so that they scratched glass. The regular hexagonal form of these crystals led me first to suppose that they belonged to the regular hexagonal system; but on passing polarized light through them I was unable to detect any traces of polarizing power, and I am inclined to think, therefore, that these crystals belong to the regular system, and present the very common case of the distortion of the regular octahedron by the abnormal development of two of its opposite sides, by which a regular hexagonal plate may be produced. Similar distortion is frequently observable in alum and nitrate of lead. What this substance may be I am unable to state. I was able to collect but a very small quantity, and that under the microscope, with the aid of a needle. I have the specimens still sealed between glass plates, and I would gladly intrust them to any one who would undertake the analysis. Fig. 1 represents one such crystal, which cost two entire days' labor to secure, because it was necessary to suppress breathing while fishing for it, as the least current of air would blow it from the needle's point, and then it would be most difficult to find again. The crystals seldom occur isolated, but for the most part in groups, as in Fig. 2. In the places marked *a*, *d*, *h*, the crystals are heaped several deep, and of very indistinct and irregular form. In the spots *b*, *c*, *e*, *g*, on the other hand, there is but one layer, and it is clearly seen that they are six-sided plates. The dimensions given in Fig. 1 show how small the crystals are, but their thinness is still more remarkable, because, under a magnifying power of 550, it was impossible to measure their thickness. Fig. 3 represents a portion of the surface of the growth on the walls of the honeycombs, and on this is seen a kind of sweat or stream of a transparent substance, which may be the same as that which has been

spoken of above, or may be different; it is not easy to determine. Fig. 4 represents the form of cavities caused by contraction or bubbles, in which I have often found the six-sided plates. Fig. 5 represents the appearance of the growths occurring in the central contraction cavities of cast ingots of hard steel. All these growths appear to have a smooth polished surface like that of a looking-glass. Fig. 6 represents the residuum remaining after dissolving steel in weak nitric acid. The substance remaining is probably silica; it is of a yellowish-brown color. The particles have the appearance of little plates, and a general appearance similar to the fracture of the steel dissolved. The study of such residuum is extremely interesting, and may lead to the elucidation of many problems concerning the structure of steel. Fig. 7 represents two grains appearing in the fracture of well-crystallized hard cast and unforged steel.

THE HISTORY OF THE STEAM ENGINE IN AMERICA.

The chronicle of the steam engine in this country has received from two sources, some valuable additions which have proceeded from the Centennial Exhibition. The first of these is a letter written by Judge Joseph P. Bradley (U. S. Supreme Court), which accompanies the exhibit of a portion of the cylinder casting of a Newcomen Engine, which is stated to have been in use in 1753 near Newark, N. J. And the second source is a paper written, and illustrated by drawings, by Fred. Graff, C.E., descriptive of the Engines and Boilers for the Water Works of Philadelphia, from the commencement of the water supply in this city in the year 1800, down to the year 1822. The previous reliable information which we have possessed as to the early use of the steam engine before the year 1803, has been founded on a "First" Report of Benjamin Henry Latrobe, member of the American Philosophical Society of Philadelphia, at the meeting of the Society, May 20th, 1803, and published in their transactions, vol. vi (1809 on the title page), in answer to the inquiry of the Society of Rotterdam, "Whether any, and what improvements have been made in the construction of Steam Engines in America?" [The second report does not appear to have been made at all.] By collating and grouping together the data afforded by these several authorities, with

some little additions from general history, an intelligible account may now be presented.

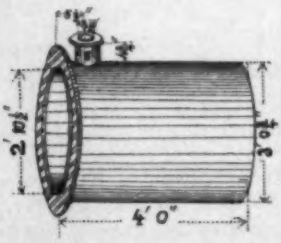
The report of Mr. Latrobe gives the priority of erection of an engine to that at the Schuyler copper mine on the eastern bank of the river Passaic, a few miles above Newark, New Jersey. This engine is the one referred to in Judge Bradley's letter. It was built by the Hornblowers, and one of the sons came to this country with it, and is of peculiar interest as being the production of the celebrated engineers, who were identified with the construction of the first practical engine ever built.

The family of Hornblower went through three generations as steam engine builders, and the recurrence of the name seems, now, not a little confusing to the reader of history. The earliest record is that of Joseph Hornblower, of Bromsgrove, Worcestershire, near Birmingham, who, in 1712, was an engine builder in Wolverhampton; and thirteen years later, in 1725, he left Staffordshire and went to near Redruth in Cornwall, and superintended (probably built) the engine at Wheal Rose mine. There were but two engines in Cornwall in 1720, one finished that year, and one built, prior, in 1714, and the Wheal Rose engine was probably the third. Joseph Hornblower had two sons, Jonathan and Josiah (if not others), who followed the business of the father. According to Judge Bradley, this American Engine was the production of their hands, about the year 1750, (possibly the father yet continued in active business); "and Josiah Hornblower, then in his twenty-fifth year, came to this country with it." "Mr. Hornblower expected to return as soon as the engine was in successful operation. But the proprietor of the mine (Col. Schuyler) induced him to remain, and within the time of two years he married Miss Kingsland, whose father owned a large plantation adjoining that of Col. Schuyler. The late Chief Justice Hornblower, of New Jersey, was the youngest of a large family of children, who resulted from this marriage."

Jonathan, the brother of Josiah, continued as an engine builder in Cornwall, and in 1770, Smeaton names the principal makers of the atmospheric engine as Jonathan Hornblower the elder, and John Nancarrow. [John Nancarrow subsequently came to this country and his descendants are yet resident in Philadelphia.] Jonathan had a numerous family of children, all brought up as engine builders and engine men.

Jonathan, Jesse, Jethro, Jabez Carter (the order of age not being certain), with possibly others, constituted the male portion of Jonathan the elder's children. The family were one and all possessed of high mechanical ability, and under ordinary circumstances would have thriven in their occupation. Their education from childhood had befitted them for leaders of men—directors of work, but on reaching the age when their talent would have been most productive of results, they found the patents of Watt had closed every door of entrance upon engine construction on them. The very constructive ability, manipulations, and implements which the family had evolved in half a century of intelligent labor, was absorbed with their business into the workshop of Boulton and Watt, while for themselves there was neither tolerance nor endurance, as foremen or workmen, in engine construction. Jonathan here named was the inventor and patentee of the compound engine, the history of which in the lawsuits with Watt is well known and subsequently he is said to have been an esteemed engineer of mines in Cornwall, and died 1812-13.

Jabez Carter was the writer of the history of the steam engine for the "Mechanics for Practical Men," of Doct. Olinthus Gregory, which history appeared complete in the first edition only, being partly suppressed in the subsequent editions, not without Doct. Gregory's protest. He died 1814, and with him the prominent connection of the family with the steam engine, after 100 years, appears to have ceased.



There will be found as the exhibit of David M. Meeker, Esq., of Newark, N. J., in the Machinery Hall, column B, 76, a cylindrical casting as shown on the accompanying sketch, which has been prepared to the scale of one-half an inch to the foot. Together with this casting there is the descriptive letter of Judge Bradley. It is a portion of the cylinder with the lower flange remaining upon it, while the upper end has been cut off, apparently in the lathe, as the edge is very straight and true. The interior surface is tolerably cylindrical and straight, with a few recesses, of perhaps an inch in one (the longest) direction across, and less than a sixteenth in depth, but the surface is otherwise generally even. It has been completely scaled by rust since it was in use, although now showing a coat-

ing of paint on evidently clean but much pitted iron. The rusting has effectually removed all indications of wear, so that it presents no marks of former work, and its identification as a "*relic*" at all, rests upon its traditional authentication. There are 12 bolt holes of 1⅜ inches diameter, equally spaced, in the lower flange—these holes were originally cast in the flange—not drilled. The nozzle (which has its flange broken off irregularly) was probably the injection nozzle, and the steam, drain and snift openings must have been in the bottom casting, an arrangement shown in drawings of Newcomen's engines, as of not unusual occurrence. This description of the casting is given with so much detail, rather for record with the facts presented by Judge Bradley, than for the instruction to be derived from the relic itself. If the usual proportions of Newcomen's engines were followed in this case, there must have been about two and a half feet more length for the cylinder, with a square flange near to the place where the cut was made. This supposition would make the original engine, about 6 feet stroke by 2 feet 10½ inches diameter.

Crude and imperfect as these Newcomen engines are popularly regarded, they have done in their day a great deal of work, and a few of them are yet to be found, not merely as neglected relics, but actually at work at the present time as they have continued to work for a century or more, in parts of England. In Dudley, South Staffordshire, near Birmingham, one instance is quoted to the writer of this article by Mr. J. C. Hoadley, of Lawrence, Mass., of an engine he saw running as recently as the year 1863.

Quoting Judge Bradley's letter to Mr. Meeker: "The steam engine of which you possess a relic was, as you suppose, the first ever erected on this continent. It was imported from England, in the year 1753, by Col. John Schuyler, for the purpose of pumping water from his copper mine opposite Belleville, near Newark, New Jersey. The mine was rich in ore, but had been worked as deep as hand and horse power could clear it of water. Col. Schuyler, having heard of the success with which steam engines (then called fire engines) were used in the mines of Cornwall, determined to have one in his mine. He accordingly requested his London correspondents to procure an engine, and to send out with it an engineer capable of putting it up and in operation.

"After 1760 the Schuyler mine was worked for several years by Mr. Hornblower himself. The approach of the war, in 1775, caused

the operations to cease. Work was resumed, however, in 1792, and was carried on for several years by successive parties. It finally ceased altogether early in this century, and the old engine was broken up and the materials disposed of. The boiler, a large copper cylinder, standing upright, eight or ten feet high, and as much in diameter, with a flat bottom and a dome-shaped top, was carried to Philadelphia. The relic in your possession was a portion of the cylinder, and was purchased by some person in Newark.

"In 1864, I met an old man named John Van Emburgh, then a hundred years old, who had worked on the engine when it was in operation in 1792. He described it very minutely and, I doubt not, accurately. It is from his description that I happened to know the kind of engine it was; although, from the date of its construction, and the use to which it was put, there could have been but little doubt on the subject."

Passing from this authenticated example of an engine, the next reference beyond question is that of Mr. Latrobe (which reference is used by Mr. Graff for some of his assertions). Mr. Latrobe says: "Steam engines on the old construction were introduced in America above 40 years ago. Two, I believe, were put up in New England before the revolutionary war, and one (which I have seen) at the copper-mine on the river Passaic, in New Jersey, known by the name of the Schuyler mine. All the principal parts of these engines were imported from England. With the Schuyler mine engine, Mr. Hornblower, the uncle of the younger Hornblower, came to America. He put up the engine, which at different times has been at work during the last thirty years, and which, notwithstanding its imperfect construction, and the faulty boring of its cylinder, effectually drained the mine.

"The only engines of any considerable power, which as far as I know, are now at work in America are the following: 1st, at New York, belonging to the Manhattan Water-Company, for the supply of the city with water. The Manhattan Company's engine is upon the principle of Boulton and Watt's double engine without any variation. It has two boilers, one a wooden one upon the construction of that first put up in Philadelphia, the other of sheet iron on Boulton and Watt's construction. The fly wheel is driven by a sun and planet motion and the shaft works three small pumps with common cranks.

"2d, one at New York, belonging to Mr. Roosevelt, employed to saw timber. [Mr. Latrobe gives no intelligible description of this engine.]

"3d, two at Philadelphia, belonging to the corporation of the city, for the supply of the city with water; one of which also drives a rolling and slitting mill. [There is no description given by Mr. Latrobe of these engines.]

"4th, one at Boston, of which I am only generally informed, employed in some manufacture."

Mr. Latrobe then adds that in his second report (never given), he proposed to describe some improvements made on an engine erected in New York... if it be found to answer the intended purpose: "Nor ought I to omit the mention of a small engine, erected by Mr. Oliver Evans, as an experiment, with which he grinds Plaister of Paris; nor the steam-wheel of Mr. Briggs."

Mr. Graff's narration now supplies a good description of the Philadelphia water works engine, and is accompanied with drawings.

These drawings of Mr. Graff are derived from the papers of his father. The senior Frederick Graff was engaged as draughtsman for the Philadelphia Water Works in 1799. These Water Works when first built had B. Henry Latrobe as engineer, John Davis as clerk of works and Fred'k Graff, draughtsman. Mr. Latrobe's connection ceased with the erection in 1801 (or 1803 at the furthest), his agreement requiring him to direct their completion. They then remained in charge of John Davis; but in 1805 Mr. Davis went to Baltimore, and Mr. Graff, who had been actively employed in an official capacity upon the Water Works until that time, became Superintendent. He remained in charge until his death in 1847, when he was succeeded as engineer of the works, by his son, the present writer.

The construction of the first engines for the Philadelphia water works were commenced in the year 1800. They were built at the Soho works of Mr. Nicholas J. Roosevelt. The Soho works were situated on Second River, three quarters of a mile west (or N. W.) of the Passaic (the Schuyler mine was on the opposite side of the Passaic, quite near this place). The location will now be found in Belleville or Bloomfield, about four miles from Newark. Messrs. Smallman and Standinger appear in the transaction, according to Mr. Latrobe, to have been the mechanics; and Mr. Roosevelt the capitalist and owner of works, or foundry.

Mr. Graff gives the following extract taken from the minutes of the committee on water works, dated July 4, 1800; being a report made by Thomas P. Cope, Esq., who was sent to examine the work upon the engines erecting at the time: this extract will give a good idea of the progress of steam engineering at that time, and serve as a measure of the advance made since:

"Took passage (from Philadelphia) in the stage for Soho Works, near Newark, New Jersey, on the morning of the 3d of July, 1800; and arrived there about noon of the next day.

"Soho is named after the works of Boulton and Watt, in England, and is situated about three-quarters of a mile northwest of the Passaic, on a small stream called Second River.

"The works consist of a smith-shop 90x40 feet, with six fires and two air furnaces; next to this is a room 30x20, in which is the fire, for heavy work; four wooden bellows play into a regulator 15x15 feet, with pipes to the forge, and four furnaces for melting and refining copper. Then there is a stone building 20x24, two stories high, with six stampers for preparing loam for the furnaces; next to this is a fitting shop with large lathe and drilling machine, and a water-wheel 20 feet diameter, to bore cannon; next to this is a shop with a water-wheel 30 feet diameter for boring large cylinders; this is now boring a small cylinder for a steamboat, which belongs to Roosevelt, Chancellor Livingston, and others.

"Higher up the stream is the furnaces, 60x50 feet, with two air furnaces capable of melting 40 cwt. of metal each, two blast furnaces for melting and refining copper, with a coal house and pattern shop, with two foot lathes; all are stone buildings; the stream affords a head and fall of 16 to 18 feet.

"The large cylinder for the engine to be used on the banks of the Schuylkill at the water works was cast in two pieces, and united by copper, the joint being secured externally by a strong band of cast-iron, eighteen inches broad, weighing 1,200 pounds. Seven thousand five hundredweight of metal was used for the cylinder; it is six and one-half feet long, and about thirty-eight and one-quarter inches in the bore; about $\frac{1}{4}$-inch throughout was at first to be cut away; one-half inch has been accomplished; two men are required; one almost lives in the cylinder, with a hammer in hand to keep things in order, and attend to the steelings (cutters); the other attends the frame on which the cylinder rests, which is moved by suitable machinery; these

hands are relieved, and the work goes on day and night; one man is also employed to grind the steelings; the work is stopped at dinner time, but this is thought no disadvantage, as to bore constantly the cylinder would become too much heated; the work also stands whilst the steelings are being changed, which required about ten minutes' time, and in ten minutes' more work they were dull again; I examined some of them and found them worn an eighth of an inch in that time. Three of these steelings (or cutters), about three and one-half inches on the edge, are fixed in the head piece at one time. The head piece is a little less than the diameter of the cylinder, and six inches thick, secured upon a rod of iron eight inches in diameter, which forms the shaft of a water wheel.

"The workmen state that the boring was commenced on the ninth of April, and had been going on ever since, three months, and about six weeks more will be required to finish it.

"The wrought iron for the flue of the boiler over the fire will be imported from England, and is in sheets 38 by 32 inches. That yet made in this country is clumsy stuff of different sizes, the largest being 36 by 18 inches, with rough edges which have to be cut smooth by the purchaser.

"July 4, 1800. Signed (THOS. P. COPE)."

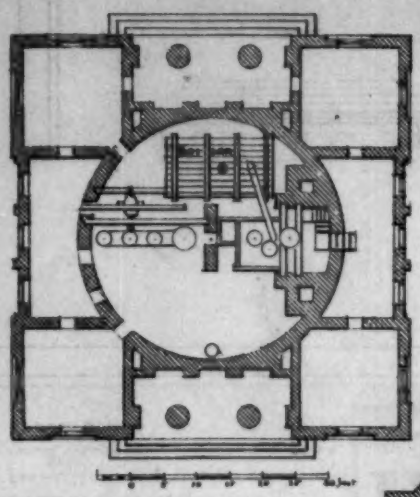
The engine for which the above described cylinder was being made was that put up at the water works on the Schuylkill, at the foot of Chestnut Street.

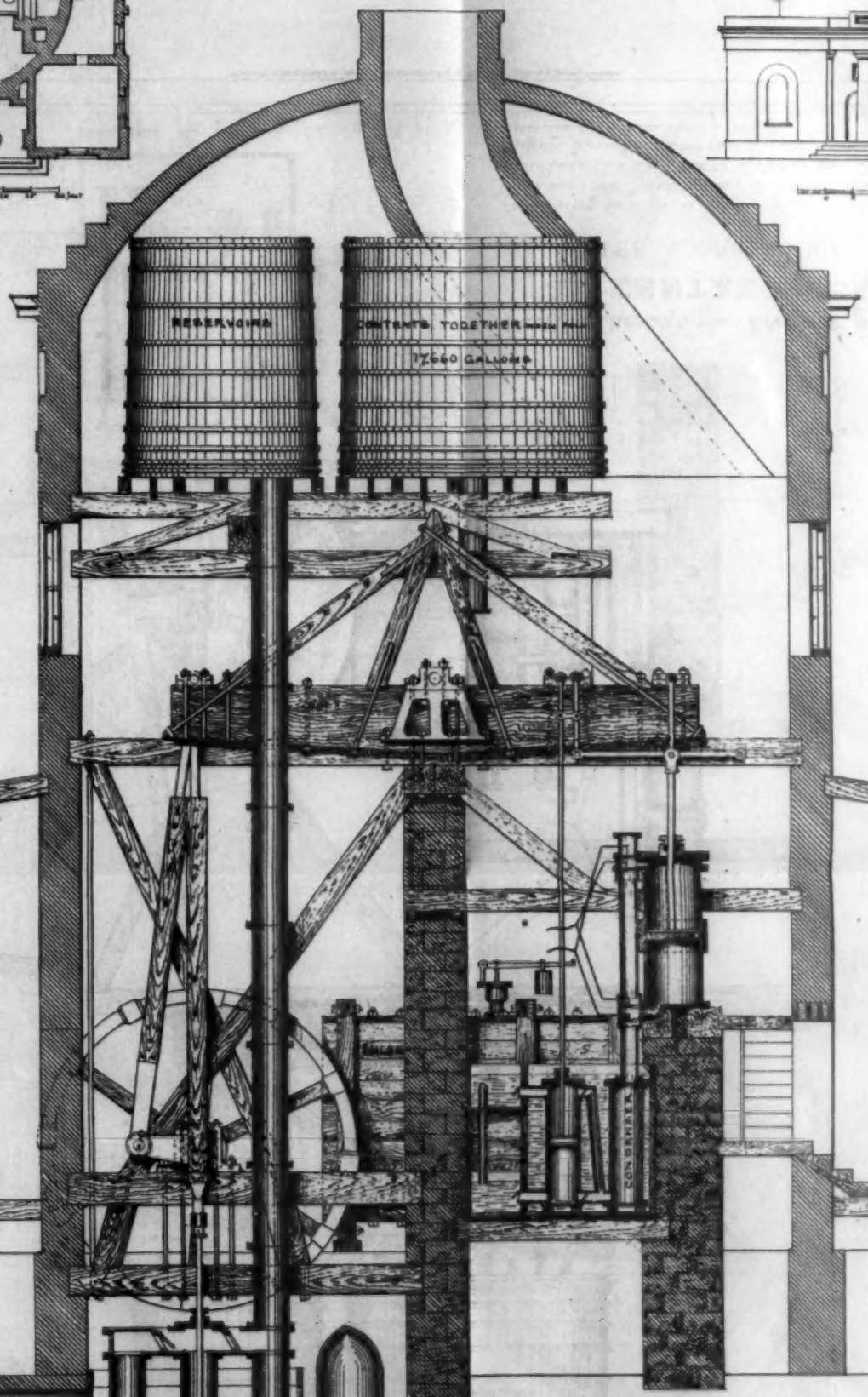
"The cylinder was 38½ inches diameter and six-feet stroke, and drove a double acting pump 17½ inches in diameter and six feet stroke."

"The engine, at Centre square, built about the same time, and at the same place, had a steam cylinder 32 inches diameter and six feet stroke, and worked a double acting pump of 18 inches diameter and six feet stroke, raising the water into tanks about 51 feet high."

"In both these engines the lever beams, the arms and shafts of the fly wheels, the bearings upon which the fly wheels were supported, the hot wells, the hot and cold water pumps, the cold water cistern, and even the external shell or outside of the steam boilers, were all made of wood."

"The boilers were rectangular chests, made of white pine planks five inches thick; they were nine feet square inside at the ends, and fourteen feet long in the clear; braced upon the sides, top, and bottom





TUNNEL SUPPLIED BY THE ENGINE AT THE SCHUYLKILL

Drawn by Frederic Graff from the original drawings and memoranda in his possession

Scale of Feet.

Section through the ENGINE HOUSE of the

CENTRE SQUARE

WATER WORKS PHILADELPHIA

Building Commenced July 1799.
Commenced Erecting the Engine February 1800.
Started the Engine to Supply the City January 21: 1801.
Supply from these works discontinued September 7: 1815.
Building taken down 1827

PHOTO-LITHOGRAPH, by P. A. WEINSMITH & CO., 1220 Chestnut Street, Philada.

with oak scantling ten inches square, the whole securely bolted together by one and a quarter inch rods passing through the planks. Inside of this chest was placed an iron fire box twelve feet six inches long, six feet wide, and one foot ten inches deep, with vertical flues, six of fifteen inches diameter and two of twelve inches diameter; through these the water circulated, the fire acting around them and passing up into an oval flue situated just above the fire box, carried from the back of the boiler to near the front, and returned again to the back, where it entered the chimney. This fire box and flues appear to have been at first made entirely of cast-iron; then a wrought-iron fire box was made, the flues still being of cast-iron; this not being satisfactory on account of the unequal contraction and expansion of the two metals causing leakage, eventually wrought-iron flues were also put in."

"Great advantage was at the time supposed to be gained by the non-conducting powers of the wood, and also by the vertical flues in the fire box."

"By experiments made with the engines when the above described wooden boiler was in use, it was recorded that the engine at Chestnut Street, on the Schuylkill, whilst lifting the water to the height of thirty-nine feet, and running at a speed of sixteen revolutions per minute, raised 1,474,500 ale gallons of 232 cubic inches each, in twenty-four hours, with a consumption of seventy bushels of Virginia coal. And the engine at Centre Square, raising the water fifty-one feet, pumped 962,520 ale gallons in twenty-four hours, with a consumption of fifty-five bushels of the same kind of coal; the pressure of steam, in both cases, being two and one-half pounds to the square inch." Taking the weight of a bushel of Virginia coal to be 100 lbs., these figures give the *duty* of the Chestnut Street engine as 4,790,000 lbs. of water raised one foot high per 100 lbs. (one bushel) of coal; and the duty of the Centre Square engine, 4,091,000 foot-lbs. The duty of an ordinary steam pumping engine to-day is about 30 millions, while the average duty of the best may possibly rise to 90 millions. The great gain has arisen from the use of higher pressure of steam than was practiced by Watt.

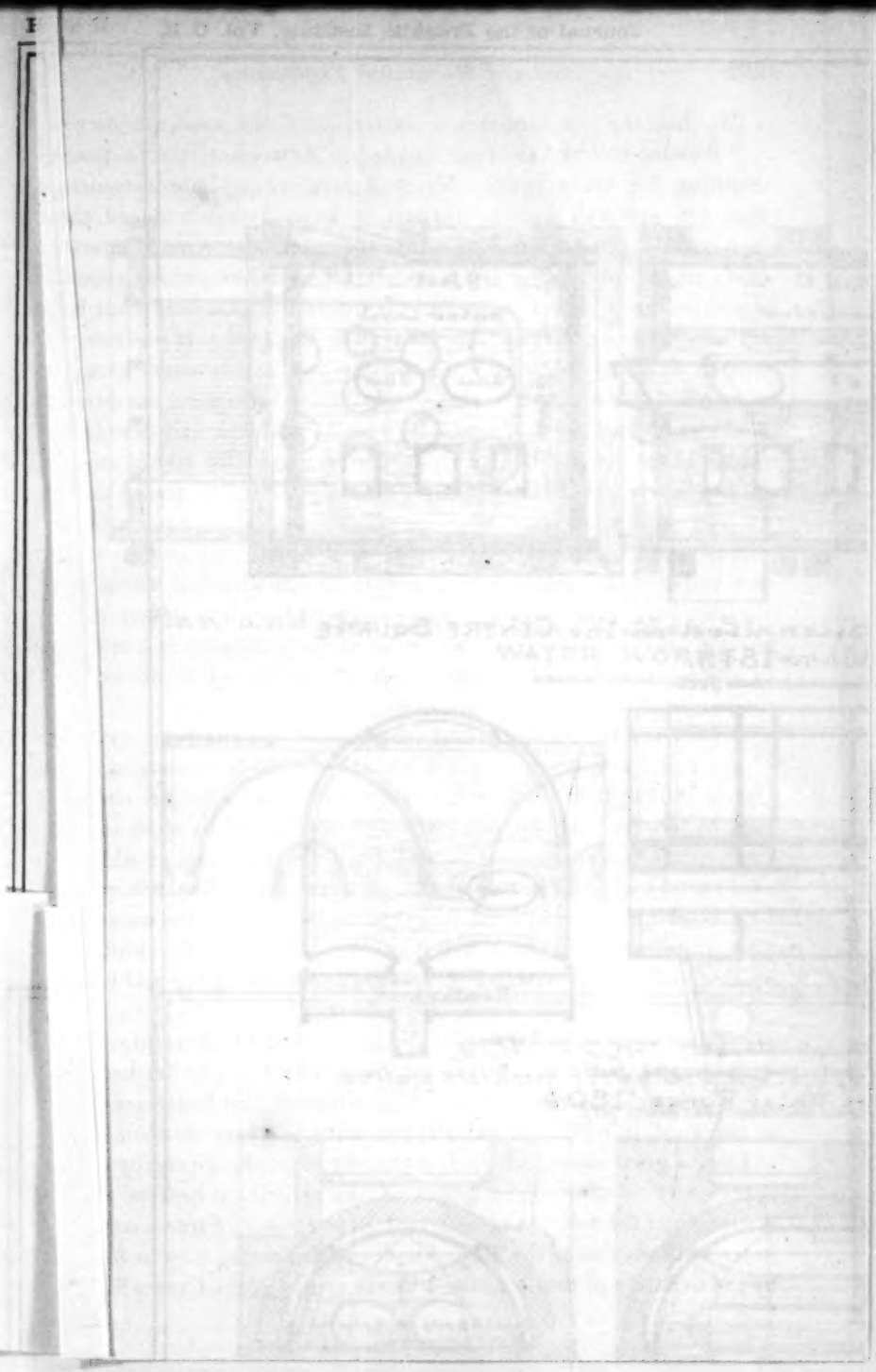
"The engine at the Schuylkill was started December 22, 1800, and that at Centre Square, January 27, 1801. The contract for them both was made March 21, 1799, the cost to be $30,000. The contractor claimed that they cost him $77,192."

Mr. Latrobe now furnishes a description of the wooden boilers:

"Wooden boilers have been applied in America to the purpose of distilling for many years. Mr. Anderson, whose improvements in that art are well known, appears to have first introduced them in America. But it was found that the mash had a very injurious effect upon the solidity of the wood: for while the outside retained the appearance of soundness, and the inside that of a burnt, but hard surface, the body of the plank was entirely decayed. It was however still to be tried whether simple water and steam would have the same effect: and upon the hint of Chancellor Livingston, our present Ambassador in France, Messrs. Roosevelt, Smallman and Staudinger contrived the wooden boiler, which has been used for all the engines in New York and Philadelphia; and not without its great, though only temporary, advantages. The construction of the wooden boiler, will be best understood, by reference to the plan and section of the new boiler of the engine in Centre Square, Philadelphia, which is by far the best of those which have been made. It is in fact only a wooden chest containing the water, in which a furnace is contrived, of which the flues wind several times through the water, before they discharge themselves into the chimney."

A plan and two sections—one longitudinal and one cross section—of this boiler are given in the Plate II—the three uppermost views "from 1801 to 1815." It will be seen that it had a flat fire chamber back of the fire box, the sides of which one stayed by short tubular castings, forming water tubes, and from the back end of which an oval up-take smoke flue passed off—this oval smoke flue was carried by a bend and a return bend forward and back, below the water line. The grate was 3 ft. long $\times$ 5 ft. wide $=$ 15 square ft., while the heating surface was nearly 360 square ft. (estimating top and bottom of chamber).

"This boiler differs from the others [*sic.* from those previously built?] in the addition of the upright cylinders of the fire-bed, and in the elliptical form of its flues. The merits of this boiler are—that as the wood, in which the water is contained, is a very slow conductor of heat, a great saving of fuel is thereby effected; especially as an opportunity is afforded, by means of the cylindrical heaters and of the length of the flue, to expose a very large surface of iron containing water to the action of the fire. An idea of this saving may be formed, by the quantity of coal consumed by the engine in the Centre Square,



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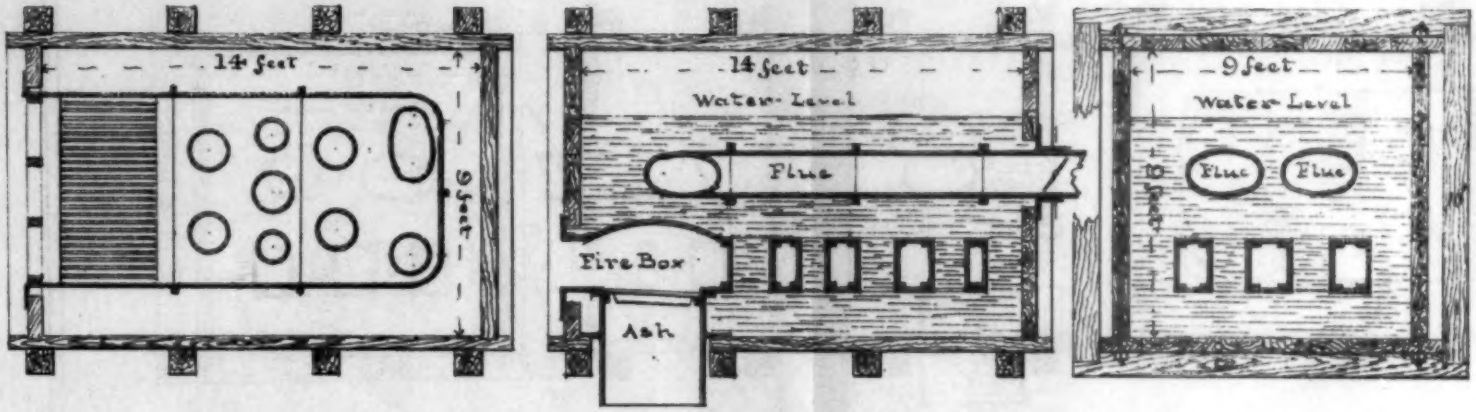
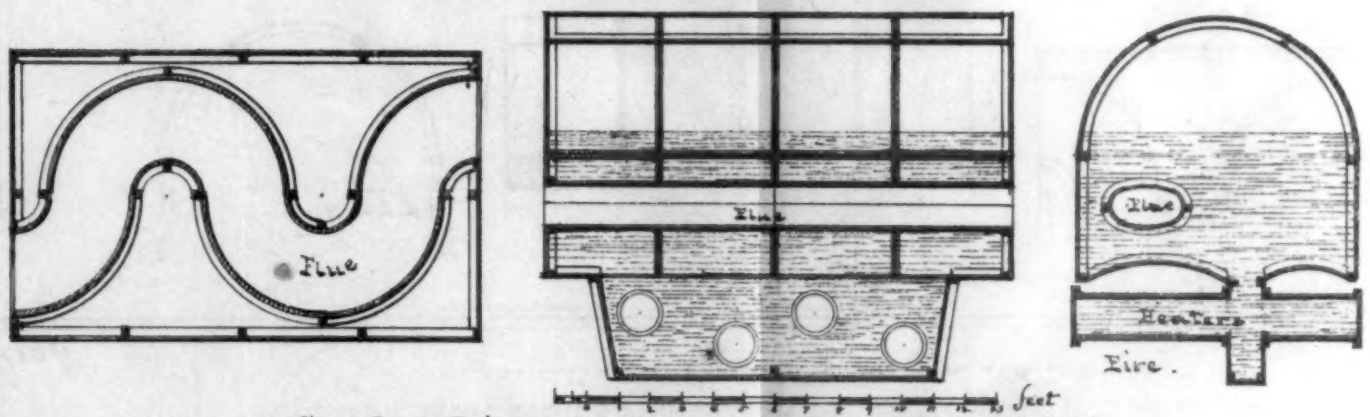
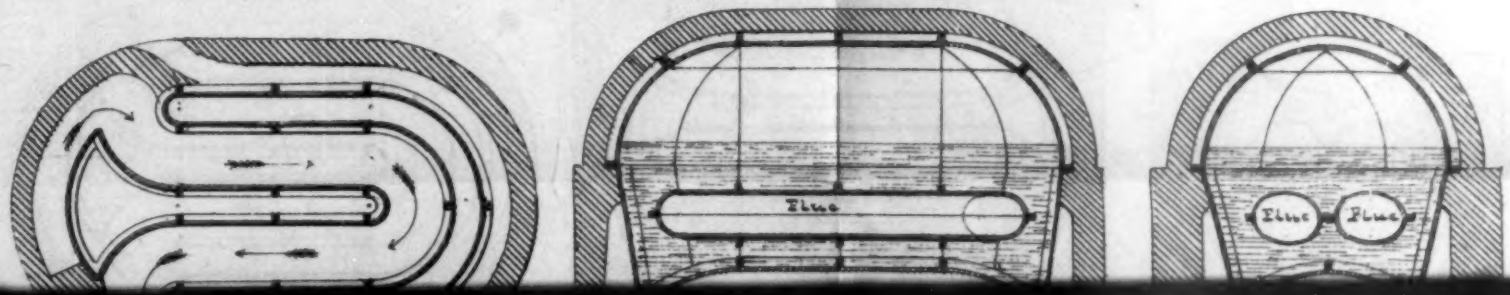


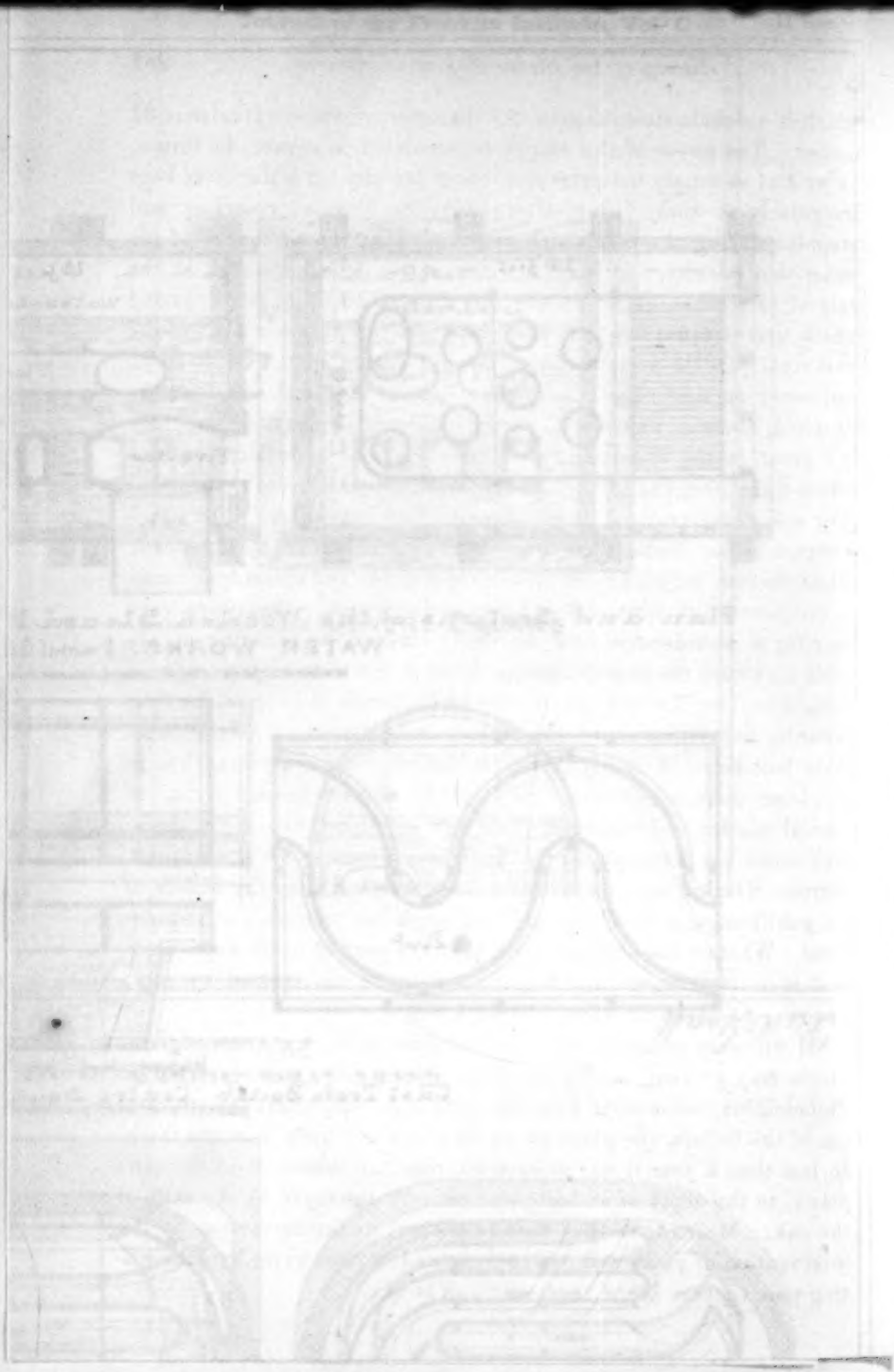
Plan and Sections of the Wooden Steam Boiler used at the CENTRE SQUARE WATER WORKS. FROM 1801 TO 1815.

feet



Cast Iron Boiler Centre Square Water Works 1804





which is a double steam-engine, the diameter of whose cylinder is 32 inches. The power of this engine is calculated to answer the future, as well as to supply the present wants of the city; it is therefore kept irregularly at work, filling, alternately, the elevated reservoir, and stopping during the time which is occupied by the discharge of the water into the city. It may, however, be fairly rated to go at the rate of 12 strokes, of 6 feet, per minute, for 16 hours in 24, during which time it consumes from 25 to 33 bushels of Virginia coals of the best sort. Of the amount of the saving, I cannot venture to make an estimate; on account of the great variety of coal with which we are supplied, much of which is of a very indifferent quality. That there is a great saving is certain; and while the wooden boilers continue steam-tight (for that part which contains the water gives no trouble), they are certainly equal, if not superior, to every other. The wood, however, which is above the water, and is acted upon by the steam, seems to lose its solidity in the course of time; and steam-leaks arise in the joints, and wherever a bolt passes through. The joint-leaks may for a considerable time be easily stopped, by screwing up the bolts that hold the planks together; but it is not so easy to cure the bolt-leaks; for the bolt, when screwed up, bends the top or the sides inwards, and forces new leaks, either along the corners, or at some other bolt-hole. I do not, however, believe, that everything has as yet been done, which could be done, to obviate these defects. A conical wooden boiler hooped would not be subject to some of them: such a one has been applied by Mr. Oliver Evans to his small steam-engine. During two years, which have elapsed since the boilers of the public engines have been erected, much has been done to improve them. Whether the last boiler will prove as perfect in its wood-work, as it is in its furnaces and flues, is still to be ascertained by experience. At present nothing can work better.

"I will only mention one other circumstance, the knowledge of which may prevent similar mischief.—In the first boiler erected in Philadelphia, oak timber was used to support the sides, bottom, and top of the boilers, the plank of which was white pine, 4 inches thick. In less than a year it was discovered, that the substance of the pine plank, to the depth of an inch, was entirely destroyed by the acid of the oak. Means were then used to prevent its further action, by the intervention of putty and pasteboard; and in most cases by substituting pine timbers in the room of those of oak."

As might be expected, great difficulty was experienced in keeping these boilers steam tight; accordingly, on December 1, 1801, a boiler with cast-iron shell, as well as flues, was put up, and another one, also of cast-iron, but of different form, was put in use March 10, 1803.

The first was erected at Centre Square. It had a semi-circular top, the ends being flat; the fire passed under the boiler around heaters of peculiar construction and through one flue of serpentine plan to the front of the boiler. This boiler had two sheets of wrought-iron upon the bottom, just over the fire, all the rest being cast-iron.

The second of these, which was erected at the works on the Schuylkill, is described by Mr. Latrobe in the following language:

"Within the last few months, a cast-iron boiler has been put up, at the lower engine, which hitherto exceeds the expectation I had formed of the facility with which steam is raised and supported by it. The engine is a double steam-engine, of 40 inches cylinder, and 6 feet stroke. The boiler has straight sides, and semicircular ends; it is 17 feet long, and 8 feet wide at the bottom; and nineteen feet long, and 10 feet wide at the height of 5 feet 7 inches. At this height, it is covered by a vault; which, in its transverse section, is semicircular; and in its longitudinal section exhibits half of its plan. The bottom is concave every way; rising one foot in the centre. The fire-place is 6 feet long, and at an average 4 feet wide; and is under one extreme end of the bottom. The fire-bed is arched, parallel with the bottom, leaving a space of one foot high, for the passage of the flame. At the end opposite to the fire-place, the flame descends along the bottom of the boiler, and, passing under an arch of fire-bricks, which protects the flanch of the bottom, strikes the side of the boiler at its extreme end. Here it enters a flat elliptical flue, which, passing into the boiler, follows its form, returning again and coming out near the place at which it entered. The entering part of the flue is separated from the returning flue, by a partition of fire-bricks. The flue, on coming out of the boiler, turns short round, and is carried round the whole boiler until it enters the chimney;" as will be more clearly shown by referring to Plate II, where the three lowermost views give the plan and two sections.

"The whole boiler is tied together internally by numerous braces, which are forked and bolted together upon the flanches, and are indispensable to prevent the boiler from bursting.

"The boiler is composed of 70 plates of iron, cast with flanches, and bolted together, so that the flanch and bolts are within the water of the boiler wherever the flame touches it; otherwise they would be burned off in a few days. The pieces are so contrived as to be of only 12 different patterns. This boiler consumed 50 bushels of coal, and ½ a cord of wood, while rolling iron 12 hours, at 20 strokes per minute, and pumping water 6 hours, at 12 strokes per minute.

"I will only further observe, that this boiler requires a very active fireman; and it is my opinion, that if it were 3 feet longer, a more moderate fire would raise the same steam and consume less fuel. The permanence of this boiler renders it very superior to the wooden one; and the difference of the consumption of fuel in each, in proportion to the size of the engine, is not great."

According to Mr. Graff, "The boilers heretofore described remained in use at Chestnut Street, Schuylkill, and at Centre Square, until the steam pumping works were started in Fairmount in 1815, at which time both the Chestnut Street and the Centre Square pumping stations were discontinued."

"In October, 1807, a new wooden fly wheel shaft was put into the Schuylkill engine, and also that at Centre Square; the latter engine at the same time had a new wooden lever beam made, the old ones being found rotten. This latter engine had a fly wheel of 20 feet diameter substituted for the wheel of 16 feet diameter, first used. Neither of the pumps were originally provided with air chambers; such an appliance was put to the Centre Square engine, June, 1810."

Mr. Latrobe says that the want of a valve on the main, or of an air vessel, "has these disadvantages—as long as the engine makes only 11 or 12 strokes per minute, no inconvenience whatever is perceived in working the pumps. But in the engine in Centre Square, which raises the water (in an 18 inch pipe) 51 feet, the attempt to work faster than 12 strokes per minute is in vain, . . . giving the engine shocks which seem to endanger every part of it."

Mr. Graff reports, "The expense of keeping the engines running in 1809 is reported:

$6,254.36 for the Schuylkill engine.
and 7,552.87 for the Centre Square engine.

$13,807.23 together.

"The engine and pump first put in at Fairmount, which was started to supply the city September 7, 1815, was almost similar to those at Schuylkill and Centre Square works, except that the lever beam and fly wheel arms and shafts were made of cast-iron. They were all on the Boulton and Watt style of that period, with poppet valves worked by hand gear and tappets.

"The dimensions of this engine were: steam cylinder 43⅛ inches diameter, and six feet stroke; lever beam, cast in two leaves, was 23 feet 9 inches long, between centres; the pump was double acting, 20 inches diameter and 6 feet stroke; the water was raised 102 feet above low tide; the boiler, as before stated, was cast-iron."

"The castings for the engine were made by Samuel Richards, at Weymouth Furnace, and at a foundry then situated within a fourth of a mile of Fairmount. The price paid was, for the cylinder castings, $160 per ton; for lever beam, $120; for fly wheel and shaft, $100; and for the cast-iron boiler plates, $90 per ton; the weight of the latter was 16 tons 12 hundredweight and 39 pounds."

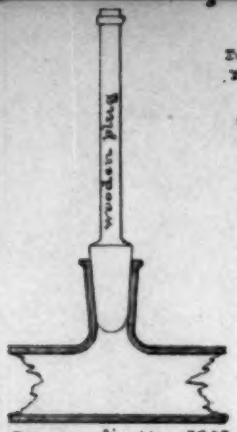
"The founder reported that the castings of the cylinder (which had to be cast with the nozzles for the side pipes separate) took all the metal that the 'Eagle Works' would hold, viz., 35 hundredweight.

"This engine, with steam at 2½ pounds above the atmosphere, raised 2,116,382 United States gallons, with the consumption of seven cords of oak wood; the run was for twenty-four hours, but after the first eight hours it was found difficult to keep the steam up to 2½ pounds pressure, and the engine finally stopped for want of steam; the chimney flue was afterwards enlarged, and then steam was carried up to 4 pounds to the square inch; the engine cost $54,341."

"The boiler at Fairmount was of cast iron, and of the same plan and internal arrangement as shown in the drawings, Plate II, for the *wooden* boiler of original use at the Centre Square. Externally the shell had a semi-cylindrical top, the whole exterior being of cast-iron. This boiler continued in use from the day of commencing to pump by steam at this station (September 7, 1815, to January 14, 1822), when steam-power was discontinued and water-power was substituted."

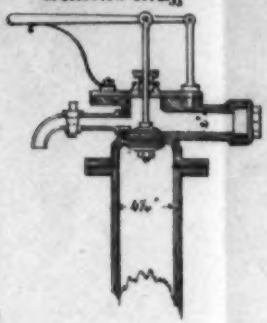
"At this Fairmount station Oliver Evans erected the first large high pressure engine made by him."

"It had a steam cylinder 20 inches diameter and five feet stroke, with a rotating steam valve, worked by bevel gear wheels, driven

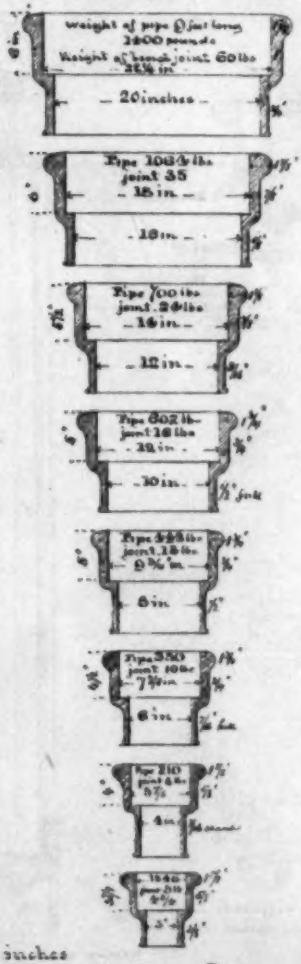


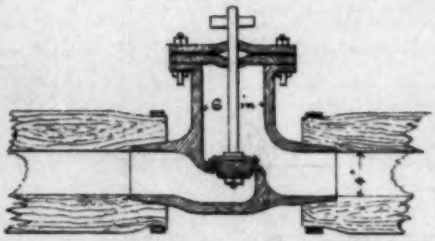
London fire plug 1803

Fire plug and Hydrant used in Philadelphia in 1803 assigned Frederick Graff

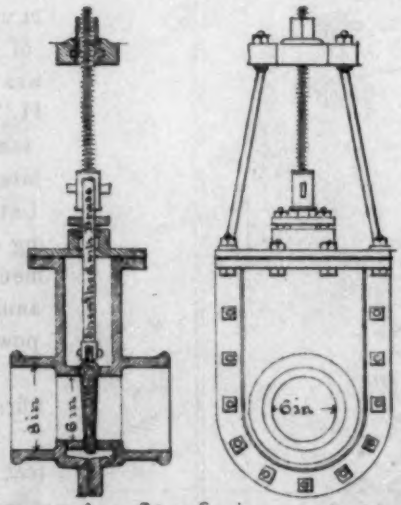


Proportion and weight of iron Pipes established by Frederick Graff for Philadelphia Jan. 1819

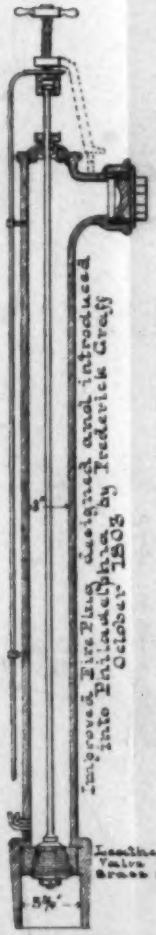




Stop used with Wooden logs in Philad^a from 1801 to 1844



Double face Stop Cock designed and introduced into Philadelphia by Frederick Graff in 1822.


Improved Fire Plug designed and introduced into Philadelphia by Frederick Graff October 1803
Leather Valve brass seat
5¾"

Scale of all inches

PHOTO-LITHOGRAPH, by P. S. WEMBERTH & CO., 1339 Chestnut Street, Philada.

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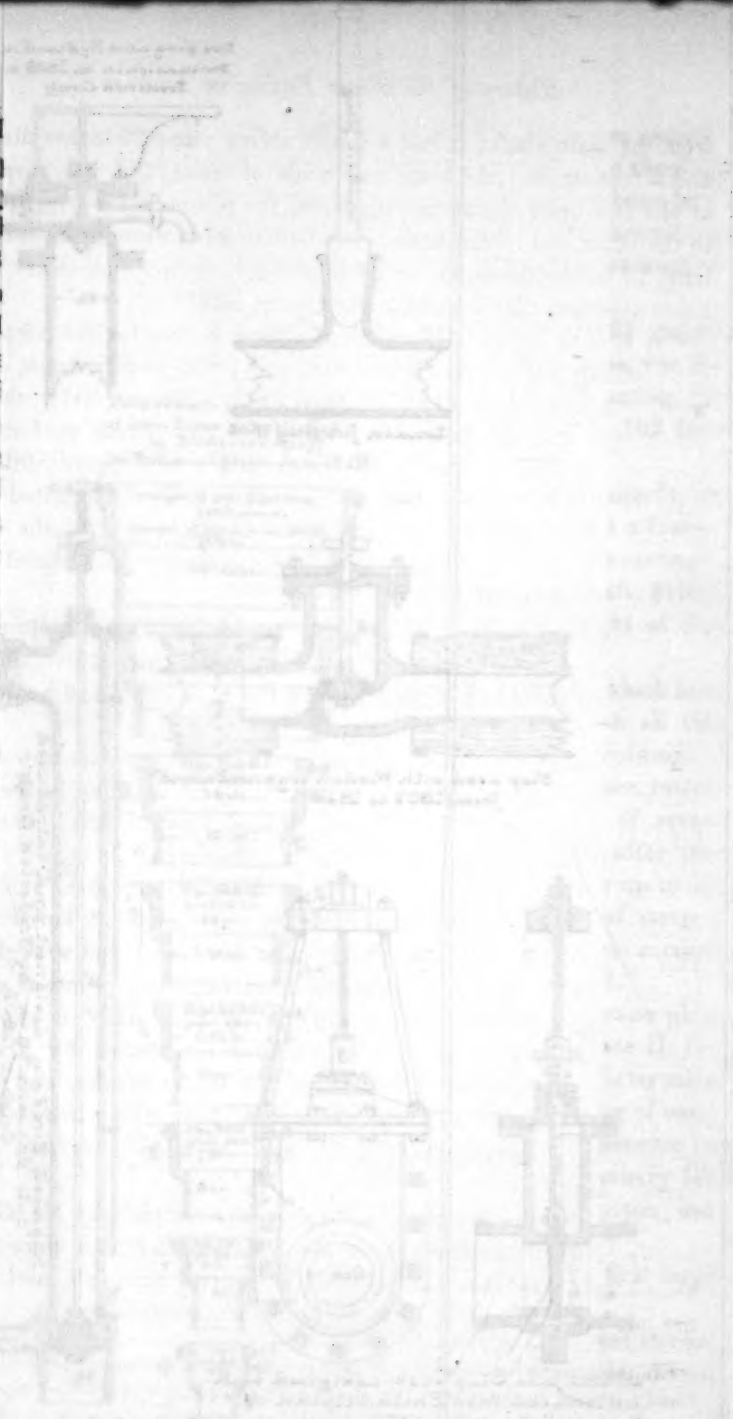

from the main shaft; it had a double acting pump 20 inches diameter and 5 feet stroke; the beam was made of wood, and was suspended at one end upon vibrating standards, the piston rod being attached to the other end of the beam. The boilers were wrought-iron, 27 feet long, 27 inches diameter, and 4 in number, upon which steam was at times raised to 220 pounds to the square inch."

"A trial or test of this engine of Oliver Evans, for the purpose of ascertaining if it would work in conformity with requirements of contract, was made on the 15th of May, 1817. Report states that the result was not altogether satisfactory. The actual performance, however, was that it run twenty-three and a half hours; filled the reservoir 9 feet 5 inches deep, being equal to 3,666,021 United States gallons, maintained steam from 194 to 200 pounds to the square inch, and burned 13 cords of oak wood, running at a speed of 22 revolutions per minute."

"The Oliver Evans boilers, with their high pressure, certainly did not give acceptable final results. They burst twice—first, June 20, 1818, when three men were killed by the explosion; and again, Oct. 12, 1821, this time without loss of life."

"The use of both these Fairmount engines was discontinued when water power was substituted. They remained standing in the building (yet in existence at Fairmount) until May 10, 1832, when they were sold, and soon after broken up and removed."

"The distributing pipes at first used in Philadelphia, and which continued in use generally until 1819, were made of bored spruce pine logs, faucet and spiggot ends, with the faucet end wrought iron banded. Although it is probable that cast iron pipe was used to some extent before the date given, for on Plate III * is shown the standard sizes adopted at that time, as established by Frederick Graff, Sr., then Chief Engineer of the Water Works, and is also shown the old stops used with the wooden logs, which it will be seen is in general arrangement much like the 'globe valves' of the present day."

"And also the fire-plugs and stop-cocks designed by Mr. Graff in 1803 and 1822; no fire-plug or stop has been invented since (to my knowledge) that does not contain the general principle, and almost the mechanical form, of these early hydraulic appliances."

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* In the American editions of "Nicholson's Operative Mechanic," 1830–31, will be found a table of thicknesses of iron in the body and weights per yard of pipes, made after the scale shown on Plate III; the scale itself is here published for the first time.

"The first of the large water mains was cast at the charcoal blast furnaces of Mr. Samuel Richards; one of the very earliest of them is to be seen in the section of the American Society of Civil Engineers, at the Centennial Exhibition. [Attached to this pipe is the following inscription: "One of the first cast iron water mains made in America, cast by Samuel Richards, laid at Broad and Market Streets, Philadelphia, June, 1820. In constant use, 53 years; made according to the specifications and system of mains, established by Frederick Graff, Sen., January 26th, 1819. The price paid for these mains was $\$7\frac{42}{100}$ per lineal foot, about 5 cents per pound; weight, each 9 ft. given length, about 1400 pounds."] It exhibits the state of the founder's art at the time when it was cast, and also shows how durable such pipes are, when conveying the water of the Schuylkill, or resisting external corrosion from the action of the soil of Philadelphia."

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. cii, page 199.]

"It should be stated that the figures and dimensions of parts of apparatus at the Market street works are from recollection of statements of the foreman of the works, and from memory of the observations by me, which were gathered in two visits to the works, of about one hour each, and they are not to be accepted as accurate data, but only as conveying to the mind the relative idea of magnitude, within close limits, to the facts.

"[§ § *Four.*] It next will be proper to show what is the approved and best practice in purifying gas at the present time for the purpose of comparison with that employed at the Market street works.

"As noticed in the first part of this affidavit, the earliest successful attempt to purify gas was by means of lime-water, and except for the difficulty of disposing of the foul water, it would probably have never been superseded.

"The wet-lime process consisted in passing the crude gas in small streams or broad, thin sheets through a mixture of lime and water of the consistency of the well-known white-wash.

"The spent material had (and has yet when used) all the filthiness of foul-lime as usually made, concentrated by about twice the proportion of objectionable substances, added to which is the absorbed ammonia in the watery portion, and the whole is liquid, so that it must be run off from the works.

"The labor attending the purifying of the gas, however, after the stirrers, vats, etc., are once established, is quite as little as is demanded by the later process of dry lime, and the purified gas resulting is excellent. Although the dry-lime process was introduced in England as early as 1815, it was quite thirty years before it superseded generally the wet-lime one in the United Kingdom; and, in 1850, in this country, the opinion of most the gas-works managers (then comparatively few in number) was as decidedly against the feasibility of purifying by dry lime, as a similar opinion was against oxide-of-iron processes in 1850.

"Professor Chandler says the wet-lime process is yet in use at Cork, Ireland, and it is probably also in use in a few other places in the kingdom.

"In this country, I think that it is only at Boston that it continues to be used, and the managers of the works are yet well satisfied with the resulting quality of the gas. I learn from Mr. W. W. Greenough, the agent and treasurer of the Boston Gas-Works, 'that the foul-lime water after use in the purifiers is run into a close tank, without any exposure to the air, where it is allowed to settle and the water drained off into a dock or tank, where it is again retained and still further clarified, almost all the lime remaining in the dock.' It can be averred, without much exaggeration, that the discharge of any foul water into the harbor of Boston will not materially increase its vileness.

"The invention of Hills', of oxide of iron as a purifying agent, was at once seized upon by British gas-makers; some paid the claimed royalties, others used the material and defended themselves, and many an expensive lawsuit followed. Hills had the satisfaction of winning and obtaining some remuneration, and at the expiration of his patent his method was so well established that none of the larger gas-works neglected to adopt it, and since that time no considerable works have been built in Great Britain using lime purification alone.

It always happens that during the existence (life) of any original patent no improvement is apparently made. This fact arises from the want of interest by those who use the patent, in the publication of what they individually are accomplishing, or improving upon, in their practice; and it followed in this case, as in others, that when, in 1863, Hill's patent expired, there was little record available in this country, describing the details of its use, although the process had met nearly universal adoption. I was, therefore, in 1866, glad to avail myself of the opportunity to see how far the oxide of iron process succeeded, and to examine the methods of use. Taking one of the larger works in the kingdom, under management of the highest reputation, for an example; I found at the Pagoda works of the Birmingham and Staffordshire Gas-Light Company, Mr. Hugh Young, manager, the process of purification was as follows:—First, 'a single purifier with *one* wooden screen only, on which was two inches of sawdust wet with weak sulphuric acid. After this the ammonia test was perfect; a paper each month [constantly exposed] being taken to show for that month of exposure at the meter no ammonia was present [had been passed].' 'Next followed for the removal of sulphur, a set of four purifiers, three of the number being in use for the purpose at any one time; each of these purifiers had two trays of oxide of iron, each seven inches deep, [the oxide] lasting one week without changing [any one of the purifiers being thus changed each three weeks,] and then requiring three days' exposure for revivification, the oxide of iron answering for three or four months before chemical change to sulphate [?] is effected to so great an extent as to impair its action, it is then sent to the chemical works to be used in the manufacture of sulphuric acid. In the bottom of these purifiers is placed one tray of two inches of hydrate of lime [dry lime as ordinarily used], which in the same time becomes snow-white carbonate by affinity with carbonic acid, this lime improves the gas two candles.'

"This was my first personal observation of the use of oxide of iron, and my time being limited, I visited no other works; but after my return to America in March, I made it a matter of great urgency upon managers of works in this country, to adopt the same or a similar process; both to avoid nuisance and reduce the cost of purifying—without success, however.

"In January, 1870, I again visited the same works and found some changes, which I communicated to my friends in this country, as follows:—'The purification is oxide of iron (red hematite ore from the bank crushed to powder, with one-third its bulk of sawdust); one ton of ore is used for each five millions of gas. Surface of oxide in purifiers, one-half what I use for lime purification, and the duration before revivification four to six times as long as is usual for the lime to become foul. The layers of oxide used are six inches to eight inches deep in the boxes, but the oxide must be spread about two or three inches thick on the revivifying floor. No offensive odor is exhaled at any time by the oxide of iron. Of course, the pressure on the purifiers is heavy—fourteen inches of water column in all. The seals of the boxes are two feet deep and the boxes four feet three inches deep, and three layers of oxide are used.

"'The arrangement is a pair of *ammonia* purifiers, 16′ by 16′ by 3′ or 4 feet, one of which is used alternately for removal of ammonia from the gas, giving to *two* sets, of four each, oxide purifiers, 20′ by 20′ by 4′ 3″ (of these oxide purifiers only three of each operate at once), and the gas from these two sets to one (of a pair of) carbonate purifiers 16′ by 16′ by 3′ or 4′. In the ammonia purifier, sawdust, damped with sulphuric acid, was used; one of them is emptied once in three weeks. With this precaution the ammonia test is absolutely perfect. The sawdust is supplied and removed for nothing. A lime-purifier is changed each three or four weeks, and the removal of carbonic acid was nearly perfect at all times. The lime could be reburned, but the farmers took it away at prices which paid for new-burnt lime. The sulphur-test was below inspection allowance always, and the gas was sixteen candles. There is no secret, mystery or trouble with oxide-of-iron purification.'

"These works are about half the size of the Philadelphia works. There are, or were, two companies in Birmingham; but the district of the Birmingham and Staffordshire Gas Company is down in my notes as thirty miles extreme length, and ten miles extreme width, with three principal works, and a make of one thousand millions per annum; and with over three hundred miles of connected mains.

"In the Paris Gas Works, at La Villette, the material known as 'Laming process' is in use, being a mixture of *prepared oxide*—that is, oxide of iron made from copperas (sulphate of iron), wood cut-

tings from a planing machine, and slaked lime in proper proportions. I find notes of this:— * * * 'The revivifying-room was strong with pure ammonia, but there was not the least offensive smell in all the works.' * *

"It would be possible for me to quote from my notes the process and a description, with proportions of the apparatus for purifying, at several works, in London particularly, but it would only exhibit a repetition of the same general facts, and it is sufficient to say here that all my observation, with the best-known works, failed to impress me any more favorably than those at Birmingham did. Since 1870, the progress of coal-gas making has changed very little, but numerous publications have been made, in which the actual practice of gas purification with oxide of iron and its adjuncts has been well described; accompanied, to be sure, by more brilliant notices of schemes, which make it difficult for a practical man to distinguish between real performance and projected expectation.

"The introduction of the use of oxide-of-iron purification in the works of the United States is yet very rare, but for some two or three years back the system has been employed at the 'New York' Gas Works in New York City, where a patent mixture of St. John and Cartwright is in use, and also more recently, at the Mutual Gas Works, another oxide-of-iron mixture is used, which is understood to be under another patent or to be a secret. On the 17th of February last I visited these works.

"At the 'New York' Gas Works, which are located on Avenue A and East Seventeenth street, (occupying two or three blocks or parts of blocks, on or near the East river), I found the ordinary construction of a modern, well-planned gas works. The operations of the works were transacted with usual care, order, and with much regard to avoid or prevent any nuisance. The several settings of benches I was told, aggregated eight hundred retorts, (13″ by 23″ by 9′), and two hundred and sixty pounds of coal was used with five changes in twenty-four hours. It was at these works that I first saw the mechanical charger before referred to. The emanations from coke-quenching and retort opening and charging, escaped at the ventilators, but as the works are on the level of the adjoining streets, the steam and smoke ascends and is dissipated so as to avoid cause of complaint.

(To be continued.)

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. cii, page 144.]

Bettendorf † prepares pure hydrochloric acid by utilizing the fact that arsenious acid in a concentrated hydrochloric solution is thrown down by protochloride of tin as a brown precipitate composed of arsenic with 1·5 to 4 per cent. of tin. He mixes the concentrated acid with a concentrated solution of stannous chloride, filters off the precipitate, and distils, thus obtaining an acid perfectly free from arsenic.

This is confirmed by Mayrhofer,‡ but Hager‖ adds that if all the arsenic is not removed by filtration, the distillate again becomes arseniferous. Dietz treats the hydrochloric acid with sulphuretted hydrogen, whilst Engel employs hyposulphite of potassium for the same purpose. Of all these processes that of P. W. Hofmann is probably the only one used on a large scale. The pure hydrochloric acid required in the sugar manufacture is chiefly prepared in certain small establishments which make their sulphuric acid from sulphur, or which have at command non-arseniferous pyrites, *e. g.*, at Saarau, in Silesia.

Chlorine and Chloride of Lime.—By far the larger portion of the hydrochloric acid evolved in Leblanc's soda process is utilized in the preparation of chlorine as an intermediate product in the manufacture of chloride of lime. As is well known, the native peroxide of manganese (pyrolusite) has long been employed for this purpose. As

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* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† Bettendorf, *Dingl. Pol. Journ.*, cxciv., 253. *Wagner, Jahresber.*, 1869, 219.

‡ Mayrhofer, *Ann. Chem. Pharmacie*, clviii., 326.

‖ Hager, *Wagner Jahresber.*, 1872, 262.

long as this mineral was to be found in sufficient quantity there was no occasion to seek out any substitute. By degrees the manganese mines became less productive, the samples in the market grew poorer in the effective ingredient, peroxide of manganese, and the prices became higher. Hence, on the one hand, experiments became necessary to re-convert the chloride of manganese—the residue from the production of chlorine—into peroxide, in order thus to reduce the outlay for manganese and to bring back a useless and troublesome residue into industrial circulation; on the other hand, attempts were made to produce chlorine without the intervention of manganese.

The first procedure for the regeneration of manganese from its residues which has met with a practical application is that of Dunlop; the chloride of manganese being decomposed by carbonate of lime, and steam at a pressure of from 2 to 4 atmospheres, and the carbonate of manganese thus formed being heated to 300° to 400° C. This procedure was carried out in the colossal establishment of Messrs. Tennant, at Glasgow, but has not been generally adopted among manufacturers of chlorine. It requires costly plant, without accomplishing the required object—a perfect regeneration of the manganic oxide. An improvement on this process, although not industrially available, was that of Clemm,* who substituted carbonate of magnesia for chalk. From the magnesium chloride formed by the decomposition of the manganese chloride he liberated hydrochloric acid by means of superheated steam, whilst the magnesia simultaneously formed was again applicable for the precipitation of fresh quantities of manganese solutions. This method, therefore, provided for the regeneration of the chlorine united with the manganese, which in Dunlop's original process was lost in the almost useless form of chloride of calcium. A method of regenerating manganese, very advantageous under certain circumstances, has been devised by P.W. Hofman, and has been successfully introduced in the works at Dieuze, and in certain German establishments. The inventor combines the regeneration of manganese in a successful manner with that of sulphur.† Hofmann precipitates the solution of manganese with the yellow polysulphides of calcium obtained by the lixiviation of vat waste after prolonged exposure to the air. The manganese sulphide

* Clemm, *Dingl. Pol. Journ.*, clxxiii., 128.

† Compare Dr. F. Tiemann's remarks on the utilization of soda residues in a subsequent part of the present report.

thus obtained, containing 57·5 per cent. of sulphur, is burnt, a part of the sulphur being recovered as sulphurous acid and conducted into the chambers. The residue is heated with nitrate of soda (1 mol. to 1 atom of manganese in the residue), and thus converted into a higher oxide of manganese, which is then transferred to the chlorine stills as a manganese of 55 per cent. Oxides of nitrogen are evolved at the same time, which, with the aid of water and air, can be condensed as nitric acid. The peroxide thus obtained consumes, indeed, 2 to 3 per cent. more hydrochloric acid than native manganese, but is much more readily soluble.

Passing over other attempts at the same object, we may mention, as a curiosity, one process which proves, at least, how intense has been the desire to regenerate manganese. Esquiron and Gouin make the ingenious proposal to revivify manganese residues for the preparation of chlorine by means of chloride of lime!

Regeneration of Manganese according to Weldon. — Recently Weldon has completely succeeded in attaining the object aimed at by so many. C. Binks and J. Macquen * had previously sought to revivify the chloride by precipitating it with the quantity of hot milk of lime needful for decomposition, passing a current of hot air through the liquid, and utilizing the precipitate thus converted into higher oxides in place of fresh manganese. But Weldon was the first who succeeded in making the process technically applicable. His most essential improvement consists in the point that he uses not a sufficient quantity of milk of lime, but an excess. Considering the importance which Weldon's process for the regeneration of manganese has already attained in the modern manufacture of chlorine, since its commercial value is fully proved by its introduction in many establishments, especially in England, it may be considered permissible to describe its principles at greater length than the procedures already mentioned. The following account is founded partly on Mr. Weldon's paper in the *Chemical News* (vol. xxii., p. 145), and partly on his letter to Dr. A. W. Hofmann, dated March 12th, 1874.

Whilst, according to Weldon, hydrated manganous oxide diffused in water can be only oxidized to manganic oxide, Mn_2O_3, by forcing oxygen through the paste, it is possible, in the presence of lime or magnesia in excess, to convert the whole of the manganese into per-

* *Technologiste*, 1862, Sept. 27. *Wagner, Jahresberichte*, 1862, 237.

oxide. The latter remains united with the lime as a compound, CaO,MnO_2, or $CaMnO_3$, calcium manganite. This may be regarded either as an analogue of the hydrated peroxide of manganese, or as manganic oxide, Mn_2O_3, in which an atom of manganese is replaced by lime. Hence it follows that 1 mol. calcium manganite requires exactly as much hydrochloric acid in the preparation of chlorine as 1 mol. of Mn_2O_3. Nevertheless it is advantageous to oxidize the manganous oxide with the aid of lime, since, in the first place, the same amount of manganese performs double the duty as if it had only been converted into manganic oxide; and, secondly, the oxidation is effected with far greater ease in presence of an excess of lime. This is probably because manganous oxide is somewhat soluble in pure water or in solution of calcium chloride, and thus retards the oxidation. At least it has been experimentally proved that salts of manganese decidedly retard the progress of oxidation. If, on the other hand, there is an excess of lime, a brown solution of calcium manganite is rapidly formed, which, as experiments prove, greatly accelerates the absorption of oxygen by the deposit of manganous oxide.

Latterly, however, it has been found possible to complete the oxidation of the manganese by an increased current of air along with an increased dose of lime. Under these circumstances we may assume the formation of an acid manganite, $CaMnO_3,H_2MnO_3$. In fact, in exceptionally successful operations, calcium manganite has been obtained in which only 1 mol. of lime was present and 2 mols. peroxide of manganese. In most cases the manganese paste has the following composition:

$$0{\cdot}80 = MnO_2.$$
$$0{\cdot}20 = MnO.$$
$$0{\cdot}28 = CaO.$$

That the lime in the paste is chemically combined, and does not exist as a mere admixture, may be inferred because the product is perfectly neutral, and because lime cannot be withdrawn from it by a solution of sugar. The manganous oxide can also be oxidized by air when the lime is replaced by baryta, strontia, or soda.

On a practical scale the process is carried out as follows:—The manganese liquor from the chlorine stills is let off into tanks provided with agitators. In these it is treated with finely-divided carbonate of lime, to neutralize the free acid and to throw down any iron which may be present as oxide. The liquid is then pumped off into settling-

vats, in which it is left to become clear. Hence the clear neutral solution is run into the oxidizer—an iron cylinder, 3·66 metres in diameter and 6·61 in height. Into this, near the bottom, opens a narrow pipe which conveys steam, and one or more wider air-pipes. After the liquid has been heated to 55°—75° by a current of steam, milk of lime, prepared from finely-sifted hydrate of lime, is run in as rapidly as possible, while air is simultaneously forced in until no manganese can be detected in the filtrate. This occurs when not only all the manganese is converted into manganous oxide, but when an excess of hydrate of lime is already present. For this purpose 1·15 to 1·45 mols. lime are required to 1 mol. manganese.

Whilst air is continually introduced so much lime is added that altogether 1·5 to 1·6 equiv. of lime may be present per 1 equiv. manganese, so that, deducting the lime necessary to form chloride of calcium, only about ½ equiv. of line may be present to 1 equiv. of manganese in the mud produced. This is at first white, but becomes gradually black as air is constantly introduced. For the charge of a cylinder to yield 2500 lbs. manganese there are required, for perfect oxidation, about 4956 cubic metres of air and five hours time; per lb. MnO_2 1·982 cubic metres of air are therefore requisite, of whose oxygen 14·8 per cent. is actually utilized.

After completed oxidation the black manganese mud is passed into setting vats, in which it is allowed to deposit until its volume can be reduced one-half by syphoning off the supernatant solution of chloride of calcium. The mud thus concentrated contains about 141 lbs. peroxide of manganese per cubic metre, and is let off into suitable vessels for the production of chlorine.

The advantages of Weldon's process, according to the inventor, are:—The consumption of muriatic acid is smaller than when native manganese is employed, so that, at least in England, 4 tons chloride of lime can be produced, on Weldon's process, with the same quantity of acid which is required for 3 tons on the old process. In Germany and the Continent altogether, the proportion may be less favorable, since the English method of developing chlorine in large stills by the introduction of steam is less economical than the Continental procedure in which small chlorine stills are heated externally. But even on the Continent the balance of the consumption of acid is in favor of Weldon's process. The consumption of muriatic acid per ton of chloride of lime is 3301 kilos. at 21° B.

A second advantage of the process is that the residues consist of a perfectly neutral solution of chloride of calcium, whilst on the old process they consist of the more dangerous acid manganese solution and of solid residues not easy to remove from the stills.

The labor required in Weldon's process is less than the old procedure, and the men are less injured by chlorine. For, since the agents, manganese mud, milk of lime, and muriatic acid, and also the residues are all liquids, it is no longer necessary to open the stills and remove the solid residues. Hence every occasion for polluting the air of the still-house by the introduction of chlorine is obviated. The stills are charged and emptied by simply opening cocks.

(To be continued.)

PHYSICS OF THE ETHER.

By S. Tolver Preston.

[With some hesitation, and at considerable inconvenience, we have felt required to make room for the following reply by Mr. Preston to a review of his book which appeared in the June and July numbers of our Journal. In handing the work to our correspondent for notice, we had no expectation of having to publish more than some half a dozen pages; and we fear that a very small number of our readers will take much interest in a discussion so purely theoretical in character. In the interests of "fair play" we could not, however, graciously refuse Mr. Preston a hearing; although we have been compelled to abbreviate by omitting some amplifications and illustrations of his views, to be found substantially in his book.—Ed.]

Since a review of my work ("Physics of the Ether")* has appeared in your valuable Journal (in two consecutive numbers for June and July), and since the reviewer has put a construction upon certain points in the work which would convey an impression different from what I had intended, I am sure therefore you will do me the justice of allowing me to point this out, and also to notice a few of the salient objections brought forward by the reviewer—lest my silence might

**Physics of the Ether*, by S. Tolver Preston; published by Messrs. E. & F. N. Spon, Charing Cross, London; & 446 Broome street, New York.

be misinterpreted. First at page 410 of the June number of your Journal, the reviewer quotes the following passage from my work (page 33, § 48). "A molecule of matter surrounded by the ether cannot possibly be in motion without disturbing the ether, and thereby giving up a dissipating continually its motion in the surrounding ether." Then the reviewer referring to the experimental fact observed by Dr. Guthrie of the attraction of a piece of card by a vibrating tuning fork, remarks as follows.—"The tuning fork expending its motion on the resisting air in order to produce a mechanical effect on the suspended card, could not continue its vibrations a single minute, did not Mr. Guthrie stand by with his violin bow to excite the motion. But where is the 'prime motor' to fiddle the molecule into continued activity?" My answer to this is that the *sun* is the prime motor or agent concerned in maintaining the vibrations of the molecule—and this I show in the same paragraph of my book as follows: (§ 48) "It follows therefore from this that the motion of molecules which is being continually dissipated in the ether must be sustained by some external source of motion, or otherwise the motion of molecules would soon cease. This is illustrated by the known fact that the motion of molecules is sustained by the sun, it being an important fact to observe that the character of the sustaining motion is a *vibratory* or wave motion traversing the ether."

Considering that the relatively almost infinitesimally feeble vibrations of masses (such as tuning forks, etc.) have been observed to produce distinct phenomena of "attraction" and "repulsion"—may it not rather be asked how, considering the enormous vibrating energy of molecules, the teaching of such facts can be consistently ignored? Can a different kind of reasoning be applied to a molecule than to a mass, or can the scale or dimensions of the vibrating portion of matter affect the reasoning? Is it not also important to draw deductions from experimental facts, or not to neglect the teaching of nature? The reviewer says that I build entirely on the "sandy foundation" of the experiments of Dr. Guthrie. It may be reasonably asked, with what propriety a foundation of experimental fact can be termed a "sandy foundation?"

The reviewer further remarks that I recognize "no such action as a fall in nature." I can only say that this is not really the fact, as for example at page 122 of my work, I state—"There are certain known facts which would tend to the conclusion that the action of the

ether in 'gravitation' was the main physical cause concerned in the original development of the sun's heat."

Another important consideration is that in accordance with the theory of "action at a distance," all the molecular actions such as "cohesion," "chemical attraction," etc., must be assumed to exist whether the molecules of matter are in motion or not in motion (*i. e.* at the absolute zero), and so by the cooling down of the sun, the matter forming it must be assumed in accordance with this theory to be irrevocably locked together by forces which preserve their full intensity even at the absolute zero (or by the cessation of molecular motion).

Now by a reference of the molecular distant actions to the molecular vibrations, or by recognizing that molecular motion is concerned in the molecular actions, or that these actions are simply dependent on and determined by molecular motion, then it is at least so far *certain* that at the absolute zero of temperature or at the cessation of molecular motion, all molecular action would cease to exist. It certainly is not implied that this solves the problem as to the possible separation of matter at a low temperature or the possible renewal of activity; but at least it may be said that the cessation of the force which locks matter together is the main key to render an eventual separation possible—also as I have pointed out in my work, the enormous quantity of disintegrated and dispersed matter *known* to exist in the form of meteoric systems, as dust, etc., deserves at least recognition as possibly affording physical evidence of a disintegration of matter affecting itself at a low temperature, or in portions of space far removed from the sun's influence. It at least appears difficult to account for the origin of such vast quantities of disintegrated matter in space unless some such cause as the above was at work.

The reviewer (page 407) appears to find a difficulty in accounting for the conservation of vis viva at the encounter of two particles of ether—and the consequent rebound of the particles. Now I would say that there would be no authority for assuming that there was a disappearance of vis viva at the encounter of the particles unless it could be said where the vis viva went to. From the fact that vis viva is indestructible, the motion of the particles is simply changed in direction at the encounter. We may hope to have a more satisfactory insight into these facts by a more accurate knowledge regarding the ultimate constitution of matter.

The reviewer remarks (page 405) that I am puzzled by the theory of "action at a distance"—"Like others of his class he is puzzled by —and cannot 'comprehend' action at a distance; therefore he is clear that it must be a fallacy." I must demur to this, for that which cannot appeal to the intellectual powers cannot puzzle, indeed the shallow nature of the theory is an argument for its rejection. Newton, as is well known, in his celebrated letters to Bentley, declared the theory to be to him an apparent "absurdity." Indeed, any unprejudiced thinker who seeks only for truth cannot surely fail to see that the theory merely consists in the assumption of the practicability of a thing without a conception of the means, which could alone form a reasonable ground to support the assumption. It surely must also be obvious, that a theory which is in itself vague cannot possibly throw the slightest light upon anything; and, therefore, to apply this theory to physical phenomena is simply to stamp them beforehand as inexplicable. Newton, in discovering the remarkable *fact* that two masses of matter situated at a distance tended to move towards each other, and that when placed at different points of space and left free to move, the energy of the movement varied in the complex ratio of the *square* of the distance of the two masses, took care not to arrogate to himself the discovery of the *cause* of this remarkable fact.

In the July number of your JOURNAL the reviewer remarks (page 64): "This radical fallacy of the 'indestructibility of *motion*' has, unfortunately, gained a considerable acceptance, and has received the support of names much higher than that of Mr. Preston." This is, undoubtedly, true; indeed, from the very fact that the whole tendency of modern science is towards the rejection of the theory of "action at a distance," and since, by the rejection of this theory, the doctrine of the Indestructibility of Motion (or the Conservation of *vis viva*), becomes an indisputable and necessary fact; it may, therefore, be truly said that the great principle of the Indestructibility of Motion is gaining acceptance in the present day. To term the principle a "radical fallacy" can, therefore, only be a dogmatic assertion, to establish which it would be necessary to prove the theory of "action at a distance" to be *true*, which has not yet been done, and that, possibly, for good reasons.

At p. 66 of your JOURNAL, the reviewer further remarks: "Although in terms Mr. Preston accepts the modern doctrine of the

'conservation of energy,' yet, as this is expressly applied by him to the infinite store normally existing in the *ether*, and as the quantity of energy manifested by matter is declared to be variable, it is too obvious to remark that the grand theorem becomes practically valueless, and that all the attempts hitherto made to deduce the principle from the deportment of sensible matter are utterly illusory and fallacious." I am at a loss to understand how this conclusion is drawn. Firstly, is it not a generally accepted fact that the "quantity of energy manifested by matter is variable?" The sun or the whole solar system, for example, is losing energy by transference to the *ether* (*i. e.*, by radiation). The energy contained in the matter forming the sun is, therefore, variable or varying—the same holding true of other stellar suns of the universe. The "dissipation of energy" in the ether is, indeed, an accepted fact supported by Thomson and others. It is, therefore, an accepted fact that the quantity of energy in matter is variable; therefore, I am at a loss to understand the criticism on this point. Secondly, as to the remark, "all the attempts hitherto made to deduce the principle (the conservation of energy) from the deportment of sensible matter, are utterly illusory and fallacious." I cannot see how this inference is arrived at. Surely to support the principle of the Conservation of *vis viva*, or the Indestructibility of Motion, can be only to *supplement* present knowledge by the principle that in all cases where *vis viva* or motion apparently disappears, it is imparted to the surrounding medium or ether, and not lost as *vis viva;* and that in all cases where motion appears to *originate* in matter, it is, in reality, derived from the surrounding ether, the collective sum total of *vis viva* remaining at every instant *constant and invariable.*

As regards this subject (at page 65), the reviewer makes the following remarks: "When the ram of a pile driver is laboriously raised to its highest position, and there held by the grapple, what has become of the motion employed in raising it? Has the arrested lifting power been converted into heat vibrations, carefully conserved and patiently waiting to be re-converted into falling motion when the director shall release the detent? Surely such an idea can hardly be entertained for one moment, by an intelligent physicist. Supposing that for sufficient reason it is determined not to let the ram fall until the following day, where then is the motion of elevation hiding itself all this time." As to the question, "what has become

of the motion employed in raising the ram?" this is a reasonable inquiry; and as to the motion being "converted into heat vibrations," I would maintain that even this might be regarded by the intelligent physicist with more satisfaction than the evident fiction, that the motion has become "latent" (much in analogy with the old theory of "latent" heat), or stored up in a non-material or spiritualistic form in the raised ram block. However, we are not reduced to the unfounded assumption of conversion into heat vibrations, for by unfettering the reason, by rejecting the theory of "action at a distance," and taking the principle of the Indestructibility of Energy for our guide, we can deduce therefrom, with certainty, the inevitable conclusion that the motion transmitted through the ram block in the act of raising it, must have been imparted to external matter (*i. e.*, to an external medium), or, otherwise, the motion would have been annihilated.

The reviewer adds (page 69): "No physical phenomenon is better established, than that *motion* (whether of molecules or masses) is constantly originating from that which is *not* motion; *i. e.*, from static *position*, as in combustion and explosion, in the galvanic battery, in the equipoised avalanche, in the overloaded suspension bridge, in the bursting water reservoir. These simple but pregnant facts outweigh all suppositions, and for such examples of reposing power, no better name has yet been devised than 'potential energy,' or 'static force.' In diametrical opposition to the fundamental kinetic postulate of our author, we announce the inductive thesis that motion, of whatever form, is *invariably* the progeny of static force." The reviewer would, therefore, give the above as proofs that motion originates from static *position*. In the first place it is difficult to see what *position* has to do with the origination of motion; secondly, it is certain that the mere deportment of the visible masses to the eye, as in the above cases, can prove nothing whatever, though it might perhaps satisfy the superficial observer who is wont to regard visible masses as including all things essential in the universe. To arrive at the true interpretation of these facts, something more than the eye is required, or it is necessary to look deeper and use the reason.

Surely, if the action of the air on masses be imperceptible to the senses, as in the case of the movement of a card towards a vibrating fork, how much more must this be the case with the action of the impalpable ether on the masses and molecules of matter.

I cannot, lastly, but refer to the apparent inconsistency of any supporter of the theory of "action at a distance," complaining of too great boldness in speculative reasoning. Surely the wildest speculation would be tame compared with the theory of "action at a distance," which may be truly said to rest upon no rational basis whatever, and was justly condemned by Newton and Faraday. An attempt to surmount the chasm of an unknown cause by a bridge even of the most feeble mechanism, is surely far better than to assume that no bridge is required, and to do nothing.

PHYSICS OF THE ETHER.

Mr. Editor:—With your permission, I propose to comment very briefly on Mr. Preston's reply to the reviewer of his treatise,—rather because I suppose that it will be expected by the few who may take any interest in the subject, than because I feel any great occasion, or any strong impulse to rejoin.

Mr. Preston's answer to the query, where is the prime motor, to *continue* the molecular vibration required for the incessant "attraction" in matter,—that "the *sun* is the prime motor" (p. 279), is obviously a shifting instead of a meeting of the difficulty; since according to his theory the sun itself has no "prime motion," but is continuously fiddled by the *ether*.* And it was in reference to this very difficulty that on the following page (411) occasion was taken to set forth the contrasted view according to the doctrine of the conservation of force, that the continuity of thermal impulse "is maintained *only* by the fresh impacts resulting from the recoils of minute successive 'falls' of material molecules." And when the solar molecules have reached their limit of *fall*, their "working" power, or potential energy will have been entirely exhausted and dissipated. This is, of course, directly contrary to the author's teleological views.

But how can the "experimental fact" displayed by Prof. Guthrie be termed with propriety a "sandy foundation" for Mr. Preston's superstructure? (p. 279). Simply because the observed "fact" has no relation or analogy to the case in hand. Admitting the ether to

* "The ether," says Mr. P., "must be the *source* of all the motions of matter: for matter cannot evolve motion out of itself;"—and "matter cannot in any case constitute a *source* of motion."

be gaseous, we might reasonably believe that an action between two contiguous molecules, similar in character and *extent* to the action between a tuning fork and a card, should exist. But the relative distance of molecules from each other demonstrably exceeds the greatest range of "approach by vibration" that ever has been or ever can be produced by Mr. Guthrie's very interesting experiments. Denying the ether to be "gaseous," there is not even the "sandy" foundation of a crude surface analogy for Mr. P. to rest his fabric upon.

When our author declares (p. 279) that it "is not really the fact" that by his scheme "there is no such thing as a *fall* in nature; there is only *propulsion;*" his very illustration fully sustains the reviewer's statement. It is scarcely profitable to descend to a verbal dispute.

Mr. Preston very correctly says (p. 280) that on the received view "all the molecular actions such as 'cohesion,' 'chemical attraction,' etc., must be assumed to exist whether the molecules of matter are in motion or not in motion (*i. e.* at the absolute zero)." And every known fact of observation fully confirms this conclusion. But Mr. P. logically infers from his own postulates that it would be "*certain* that at the absolute zero of temperature or at the cessation of molecular motion, all molecular action would cease to exist" (p. 280). He has a vague idea that the finely divided matter found to exist in meteoric systems, has become thus segregated by reason of the suspension of cohesion in a temperature of absolute zero; and he thinks it otherwise "difficult to account for the origin of such vast quantities of disintegrated matter in space" (p. 280). Surely it is quite as comprehensible that the extremely attenuated matter of primæval nebulæ should have condensed into metallic fog, or metallic rain drops, as into the larger drops of planetoids, or the still larger drops of planets and of suns. And in the finest dust of a meteoric rain, "cohesion" is as well exhibited as in the planet Jupiter.

The fundamental difficulty pointed out (on p. 407) as lying at the very threshold of all kinetic schemes,—that *motion* alone can give no account of elasticity,—is completely evaded. Mr. P. does not seem to apprehend the elementary proposition, that in a system of colliding bodies, the *vis viva* of the system is indestructible *only* on the condition that the bodies are "elastic." He says rather indefinitely: "From the fact that *vis viva* is indestructible, the motion of the

particles is simply changed in direction of the encounter. We may hope to have a more satisfactory insight into these facts by a more accurate knowledge regarding the ultimate constitution of matter" (p. 280).

Newton's "celebrated letters to Bentley" are of course pressed into service, as usual. But the kinematists always fail to remember that a quarter of a century later than the date of the third Bentley letter, Newton himself concluded that the ether should be rejected, because "there is no evidence for its existence;" and that with a more matured realization of the utter insufficiency of all speculations as to the *mode* of gravitative action, he ultimately fell back on the suggestion, "Have not the small particles of bodies certain powers, virtues, or forces, by which they *act at a distance?*" *

Mr. Preston constantly speaks of *action at a distance* as a "theory," as an assumption "without any conception of the means" (p. 281), thereby assuming that others must necessarily have the same *cacoethes fingendi* that he himself exhibits. The astronomer accepts the fact as ultimate, and therefore necessarily as "inexplicable," without presuming to theorize upon it. As Mr. P. has himself well remarked, "Newton, in discovering the remarkable *fact*, ... took care not to arrogate to himself the discovery of the *cause* of this remarkable fact" (p. 281).

To designate the "indestructibility of motion" a "radical fallacy," is only a "dogmatic assertion," says Mr. P. (p. 281). There are propositions in physics so fully established, that they may well be dogmatically asserted; and one of these is that motion (whether molecular or molar) is a phenomenon constantly exhibited to us as increasing or as diminishing, as originating *de novo* or as being destroyed. So far is the fallacy of the indestructibility of motion from "gaining acceptance at the present day," it is not believed to be admitted by a single physicist of any eminence. All motion expended in shaping matter must have forever disappeared, else would we have useful work accomplished without the sacrifice of energy. Every elliptical orbit, whether of satellite, of planet, or of comet, presents an endless recurrence of a large amount of motion quite destroyed at the *apo-apsis*, and of a corresponding increase of motion at the *peri-apsis*.

* In the appendix to the second edition to Newton's Optics, published in 1717, Query 31.

It was urged (p. 66) that the experimental determination of the conservation of energy must be "utterly illusory and fallacious," if the energy were only transiently exhibited by matter, and were ordinarily hiding itself in the ether. Mr. P. is "at a loss to understand how this conclusion is drawn" (p. 282); and he expatiates on the "dissipation of energy." All which being neglected, it may be replied, that the energy developed in one portion of matter being observed to be abstracted from another portion, the quantitative results obtained (the waste or dissipation being reduced to a minimum) may be accepted as a close approximation to the law. But if, as alleged, the ether, instead of being the mere *vehicle* of molecular energy, is its fountain and receptacle, it is perfectly obvious that the experimentalist has no means of measuring or of following the vagaries of force.

Rejecting "the unfounded assumption of conversion into heat vibrations" of the stopped lifting motion of the pile-driving ram, Mr. P. says that "by unfettering the reason," we may reach "the inevitable conclusion" that the motion must have been imparted to an external medium, or otherwise the motion would have been annihilated" (p. 283). It is scarcely doubtful that the experienced physicist will unhesitatingly accept the latter alternative. The previous suggestion of a "latent" motion is too good to be surrendered by the ingenious kinetists, as it might serve to bridge a good many troublesome difficulties.

"It is difficult," says Mr. P., "to see what *position* has to do with the origination of motion" (p. 283). Position, though not an originator of motion, is a condition which may indisputably give to an originator of motion a great mechanical advantage. In a warfare of stones between two savages, one at the top and the other at the bottom of a precipice, the former has gravity as an ally, and the latter as an antagonist; and the first may roll down upon his enemy, masses which the latter could not even lift. And this difference in relative efficiency or energy is purely one of "position."

In regard to the illustrations of potential energy or static force given (on page 69), Mr. P. remarks "the mere deportment of visible masses to the eye, as in the above cases, can prove nothing whatever, though it might perhaps satisfy the superficial observer" (p. 283). Visibility or imperceptibility has nothing whatever to do with the question. The examples adduced were selected because the nature